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THE CLASSIFICATION OF FISHES.

BY PRESIDENT DAVID STARR JORDAN,
LELAND STANFORD JR. UNIVERSITY.

CLASSIFICATION, as Dr. Elliott Coues has well said, is a natural function of "the mind which always strives to make orderly disposition of its knowledge and so to discover the reciprocal relations and interdependences of the things it knows. Classification presupposes that there do exist such relations, according to which we may arrange objects in the manner which facilitates their comprehension, by bringing together what is like and separating what is unlike; and that such relations are the result of fixed, inevitable laws. It is, therefore, *Taxonomy* (τάξις, array; νόμος, law) or the rational, lawful disposition of observed facts."

A perfect taxonomy is one which would perfectly express all the facts in the evolution and development of the various forms. It would be based on morphology, the consideration of structure and form independent of adaptive, or physiological, or environmental modifications. It would regard those characters as most important which had existed longest unchanged in the history of the species or type, thus considering all knowledge derived from paleontology. It would regard as of minor importance those traits which had risen recently in response to natural selection or to the forced alteration through pressure of environment, while fundamental alterations as they appear one after another in geologic time would make the basal characters of corresponding groups in taxonomy. In greater or less degree, the life history of the individual, through the operation of the law of heredity, repeats the actual history of the group to which the individual belongs. For this reason the characters appearing first in the individual are likely to have greatest importance in classification.

In a perfect taxonomy, or natural system of classification, animals would not be divided into groups nor ranged in linear series. We should imagine a series variously and divergently branched, with each group at its earlier or lower end passing insensibly into the main or primitive stock. A very little alteration now and then in some structure is epoch-making and paves the way through specialization to a new class or order. But each class or order through its lowest types is intertangled with some earlier and otherwise diverging group. A sound system of taxonomy of fishes should be an exact reflex of the history of their evolution. But in the limitations of book making, this transcript must be made on a flat page, in linear series, while for centuries and perhaps forever whole chapters must be left vacant and others dotted everywhere with marks of doubt. For science demands that positive assertion should not go where certainty can not follow.

A perfect taxonomy of fishes would be only possible through the study, by some Artedi, Müller, Cuvier, Agassiz, Gill or Traquair, of all the structures of all the fishes which have ever lived. There are many fishes now living in the sea which are not yet known to any naturalist. Many others are known to one or two, but not yet accessible to those in other continents. Many are known externally from specimens in bottles, or drawings in books, but have not been studied thoroughly by any one, and the vast multitude even of the species have perished in Paleozoic, Mesozoic and Tertiary seas, without leaving a tooth or bone or fin behind them. With all this goes human fallibility, the marring of our records, such as they are, by carelessness, prejudice, dependence and error. Chief among these are the constant mistakes of analogy for homology, and the inability of men to trust their own eyes as against the opinion of the greater men who have had to form their opinions before all the evidence was in.

The result is, again to quote from Dr. Coues:

> That the natural classification, like the elixir of life or the philosopher's stone, is a goal far distant.

It is obvious that fishes, like other animals, may be classified in numberless ways, and, as a matter of fact, by many different men they have been classified in all sorts of fashions.

> Systems have been based on this or that set of characters, and erected from this or that preconception in the mind of the systematist. . . . The mental point of view was that every species of bird (or of fish) was a separate creation, and as much of a fixture in nature's museum as any specimen in a naturalist's cabinet. Crops of classifications have been sown in the fruitful soil of such blind error, but no lasting harvest has been reaped. . . . The genius of modern taxonomy seems to be so certainly right, to be tending so surely, even if slowly in the direction of the desired consummation, that all differences of opinion, we hope, will soon be settled, and defect of knowledge, no perversity of mind will be the only obstacle in the way of success. The taxonomic goal is not

now to find the way in which birds (or other animals) may be most conveniently arranged, but to discover their pedigree, and so construct their family tree. Such a genealogical table or *phylum* (φῦλον, tribe, race, stock) as it is called, is rightly considered the only sound basis of taxonomy. In attempting this end, we proceed upon the belief . . . that all birds, like all other animals and plants, are related to each other *genetically,* as offsprings are to parents; and that to discover their genetic relationships is to bring out their true affinities—in other words, to reconstruct the actual taxonomy of nature. In this view there can be but one 'natural' classification, to the perfecting of which all increase in our knowledge of the *structure* of birds infallibly and inevitably tends. The classification now in use, or coming into use, is the result of our best endeavors to accomplish this purpose, and represents what approach we have made to this end. It is one of the great corollaries of that theorem of Evolution which most naturalists are satisfied has been demonstrated. It is necessarily a—

Morphological Classification; that is, one based solely on consideration of structure or form (μορφή, morphe, form); and for the following reasons: Every offspring tends to take on precisely the structure or form of its parents, as its natural physical heritage; and the principle involved, or the *law of heredity,* would, if nothing interfered, keep the descendants perfectly true to the physical characters of their progenitors; they would breed true and be exactly alike. But counter influences are incessantly operative, in consequence of constantly varying external conditions of environment; the plasticity of organization of all creatures rendering them more or less susceptible of modification by such means, they become *unlike* their ancestors in various ways and to different degrees. On a large scale is thus accomplished, by *natural selection* and other natural agencies, just what man does in a small way in producing and maintaining different breeds of domestic animals. Obviously amidst such ceaselessly shifting scenes, degrees of likeness or unlikeness of physical structure indicate with the greatest exactitude the nearness or remoteness of organisms in kinship. Morphological characters derived from examination of structure are therefore the surest guides we can have to the blood-relationships we desire to establish; and such relationships *are* the 'natural affinities' which all classification aims to discover and formulate. (Coues.)

A few terms in general use may receive a moment's discussion. A type or group is said to be specialized when it has a relatively large number of peculiarities, or when some one peculiarity is carried to an extreme. A sculpin is a specialized fish, having many unusual phases of development, as is also a sword-fish, which has a highly peculiar structure of the snout. A generalized type is one with fewer peculiarities, as the herring in comparison with the sculpin. In the process of evolution, generalized types usually give place to specialized ones. Generalized types are therefore as a rule archaic types.

The terms *high* and *low* are also relative; a high type being one with varied structure and functions. Low types may be primitively generalized, as the lancelet in comparison with all other fishes, or the herring in comparison with the perch; or they may be due to degradation, a loss of structures which have been elaborately specialized in their ancestry.

The sea-snail (*Liparis*), an ally of the sculpin, with scales lost and fins deteriorated, is an example of a low type which is specialized as well as degraded.

In the earlier history of ichthyology, much confusion resulted from the misconception of the terms 'high' and 'low.' Because sharks appeared earlier than bony fishes, it was assumed that they should be lower than any of their subsequent descendants. That the brain and muscular system in sharks was more highly developed than in most bony fishes seemed also certain. Therefore, it was thought that the Teleost series could not have had a common origin with the series of sharks. It is now understood that evolution means chiefly adaptation, and adaptation among fishes is almost as often degradation as advance. The bony fish is adapted to its mode of life, and to that end it is specialized in fin and skeleton rather than in brain and nerves as compared with its ancestors. All degeneration is associated with specialization. The degeneration of the blind fish is a specialization for better adaptation to life in the darkness of caves; the degeneration of the deep-sea fish meets the demands of the depths; the degeneration of the globe fish means the sinking of one line of functions in the extension of some other.

Referring to his own work on the fossil fishes in the early forties, Professor Agassiz once said to the writer:

> At that time I was on the verge of anticipating the views of Darwin, but it seemed to me that the facts were contrary to the theories of evolution; we had the highest fishes first.

This statement leads us to consider what is meant by 'high' and 'low.' Undoubtedly the sharks are higher than the bony fishes in the sense of being nearer to the higher vertebrates. In brain, muscle, teeth and reproductive structures, they are also more highly developed. In all skeletal and cranial characters the sharks stand distinctly lower. But the essential fact, so far as evolution is concerned, is not that the sharks are high or low. They are in almost all respects distinctly generalized and primitive. The bony fishes are specialized in various ways through adaptation to the various modes of life they lead. Much of this specialization involves corresponding degeneration of organs whose functions have ceased to be important. As a broad proposition, it is not true that 'we had our highest fishes first,' for in a complete definition of 'high' and 'low,' the specialized perch or bass stands higher. But whether true or not, it does not touch the question of evolution which is throughout a process of adaptation to conditions of life.

In another essay, Dr. Coues has compared species of animals to "the twigs of a tree separated from the parent stem. We name and arrange them arbitrarily in default of a means of reconstructing the whole tree according to nature's ramifications."

If one had a tree, all in fragments, pieces of twig and stem, some of them lost, some destroyed, and some not yet separated from the mass not yet picked over, and wished to place each part where he could find it, he would be forced to adopt some system of natural classification. In such a scheme he would lay those parts together which grew from the same branch. If he were compelled to arrange all the fragments in a linear series, he would place together those of one branch, and when these were finished, he would begin with another. If all this were a matter of great importance, extending over years or over many lifetimes, with many errors to be made and corrected, a set of names would be adopted—for the main trunk, for the chief branches, the lesser branches, and on down to the twigs and buds.

A task of this sort on a world-wide scale is the problem of systematic zoology. There is reason to believe that all animals and plants sprang from a single stock. There is reasonable certainty that all vertebrate animals are derived from a single origin. These vertebrate animals stand related to each other, like the twigs of a gigantic tree, the lowermost branches are the aquatic forms to which we give the name of fishes, with their still more primitive fish-like relatives.

The aquatic vertebrates, reasonably called by the names of fishes, constitute about three classes, or larger lines of descent. There are lampreys, sharks and true fishes. If we include the extinct forms, we may perhaps add two more, but this is uncertain, while below the fishes are the protochordate classes of Enteropneustans, Tunicates and Lancelets, which stand nearer to fishes than to anything else. Each of these groups differs from the others in varying degree.

Each of these again is composed of minor divisions called orders, each containing many species. The different species, or ultimate kinds of animals are again grouped in genera. A genus is an assemblage of closely related species grouped around a central species as type. The type of a genus is, in common usage, that species with which the name of the genus was first associated. The name of the genus, as a noun, taken with that of the species, which is an adjective in signification, if not in form, constitutes the scientific name of the species. Thus *Petromyzon* is the genus of the common large lamprey; *marinus* is its species, and the scientific name of the species is *Petromyzon marinus*. *Petromyzon* means stone-sucker; *marinus* of the sea; thus distinguishing it from a species called *fluviatilis*, of the river.

In like fashion all animals and plants are named in scientific record or taxonomy.

A family in zoology is an assemblage of related genera. The name of a family, for convenience, always ends in the patronymic *idæ*, and it is always derived from the leading genus, that is, the one best

known or earliest studied. Thus all lampreys constitute the family Petromyzonidæ.

An order may contain one or more families. An order is a division of a larger group; a family, an assemblage of related smaller groups. Intermediate groups are often recognized by the prefixes *sub* or *super*. A subgenus is a division of a genus. A subspecies is a geographic race or variation within a species; a superfamily, a group of allied families.

Binominal nomenclature, or the use of the name of genus and species as a scientific name was introduced into science as a systematic method by Linnæus. In the tenth edition of his 'Systema Naturæ' published in 1758, this method was first consistently applied to animals. By common consent, the scientific naming of animals begins with this year, and no account is taken of names given earlier, as these are, except by accident, never binomial. Those authors who wrote before the adoption of the rule of binomials and those who neglected it are alike ruled out of court. The idea of genus and species was well understood before Linnæus, but the specific name used was not one word but a descriptive phrase, and this phrase was changed at the whim of the different authors. Examples of such names are these of the West Indian trunk-fish, or Cuckold: *Ostracion tricornis* of Linnæus. Lister refers to a specimen in 1686 as *Piscis triangularis capiti cornutis cui e media cauda cutanea oculeus longus erigitus.* This Aretdi alters in 1738 to *Ostracion triangulatus aculeis duobus in capiti et unico longioro superne ad caudam.* This is more accurately descriptive and it recognizes the existence of a generic type, *Ostracion,* or trunk fish, to cover all similar fishes. French writers transformed this into various phrases beginning: *Coffre triangulaire a trois cornes* or some similar descriptive epithet, and in English or German it was likely to wander still farther from the original. But Linnæus condenses it all in the word *tricornis,* which although not fully descriptive, is still a name which all future observers can use and recognize.

It is true that common consent fixes the date of the beginning of nomenclature at 1758, but to this there are many exceptions. Some writers date genera from the first recognition of a collective idea under a single name. Others follow even species back through the occasional accidental binomials. Most British writers have chosen the final and completed edition of the 'Systema Naturæ,' the last work of Linnæus' hand in 1766, in preference to the earlier volume. But all things considered, justice and convenience alike seem best served by the use of the edition of 1758.

Synonymy is the record of the names applied at different times to the same group or species. With characteristic pungency Dr. Coues defines synonymy as 'a burden and a disgrace to science.' It has been found that the only way to prevent utter confusion is to use for each

genus or species the first name applied to it and no other. The first name, once properly given is sacred because it is the right name. All other later names, whatever their appropriateness in meaning, are wrong names in taxonomy. In science, of necessity, a name is a name without any necessary signification. For this reason and for the further avoidance of confusion, it should remain as it was originally spelled by the author, obvious misprints aside, regardless of all possible errors in classical form or meaning. This rule is now generally adopted in America, because attempts at classical purism have simply produced confusion. The names in use are properly written in Latin or in latinized Greek, the Greek forms being usually preferred as generic names, the Latin adjectives for names of species. Many species are named in honor of individuals, these names bearing usually the termination of the Latin genitive, as *Sebastodes gillii, Liparis agassizi.* In recent custom all specific names in zoology are written with the small initial; all generic names with the capital.

One class of exceptions must be made to the law of priority. No generic name can be used twice among animals, and no specific name twice in the same genus. Thus the name *Diabasis* has to be set aside in favor of the next name, *Hæmulon,* because *Diabasis* was earlier used for a genus of beetles. The specific name, *Pristipoma humile,* is abandoned, because there was already a *humile* in the genus *Pristipoma.*

In the system of Linnæus, a genus corresponded roughly to the modern conception of a family. Most of the primitive genera contained a great variety of forms, as well as usually some species belonging to other groups dissociated from their real relationships.

As greater numbers of species have become known, the earlier genera have undergone subdivision until in the modern systems almost any structural character not subject to intergradation and capable of exact definition is held to distinguish a genus. As the views of the value of characters are undergoing constant change, and as different writers look upon them from different points of view, or with different ideas of convenience, we must have constant changes in the boundaries of genera. This brings constant changes in the scientific names, although the same specific name should be used whatever the generic name to which it may be attached. We may illustrate these changes and the 'burden of synonymy' as well by a concrete example. The horned trunk-fish or cuckold of the West Indies was first recorded by Lister in 1686 in the descriptive phrase above quoted. Artedi in 1738 recognized that it belonged with other trunk-fishes in a group he called *Ostracion* treating the word as a Latin masculine although derived from a Greek neuter diminutive (ὀστρακίον, a small box). This, to be strictly classic, he should have written *Ostracium,* but he preferred a partly Greek form to the Latin one. In the Nagg's Head Inn in London, Artedi saw a

trunk-fish he thought different, having two spines on the tail, while Lister's figure seemed to show one spine above it. This Nagg's Head specimen Artedi called *Ostracion triangulabus duobus aculeis in fronte et totidem in imo ventre subcaudalesque binis.*"

Next came Linnæus, 1758, who named Lister's figure and the species it represented *Ostracion tricornis,* which should in strictness have been *Ostracion tricorne,* as ὀστρακίον, is a neuter diminutive. The Nagg's Head fish he named *Ostracion quadricornis.* The right name is *Ostracion tricornis,* because the name *tricornis* stands first on the page; but *Ostracion quadricornis* has been most used by subsequent authors, it being nearer correct as a descriptive phrase.

In 1798, Lacépède changed the name of Lister's fish to *Ostracion listeri,* a needless alteration which could only make confusion.

In 1818, Professor Mitchill, receiving a specimen from below New Orleans, thought it different from *tricornis* and *quadricornis* and called it *Ostracion sex-cornutus.* Hollard in 1857 named a specimen *Ostracion maculatus,* and at about the same time Bleeker named two others from Africa which seem to be the same thing, *Ostracion guineensis* and *Ostracion gronovii.* Lastly Poey calls a specimen from Cuba *Acanthostracion polygonius,* thinking it different from all the rest, which it may be, though the chances are to the contrary.

This brings up the question of the generic name. Among trunk-fishes there are four-angled and three-angled kinds, and in each form species with and without horns and spines. The original *Ostracion* of Linnæus we may interpret as being based on *Ostracion cubicus* of the coasts of Asia. This we call the type species of the genus, as the Nagg's Head specimen of Artedi was the type specimen of the species *quadricornis,* or the one that was used for Lister's figure, the type specimen of *tricornis.*

Cubicus is a four-angled species, and when the trunk-fishes were regarded as a family, Ostraciidæ, the three-angled ones, were set off as a separate genus. For these forms two names were offered, both by Swainson in 1839. For *trigonus,* a species without horns before the eyes, he gave the name *Lactophrys,* and for *triqueter,* a species without spines anywhere, the name of *Rhinesomus.* Several recent American authors have placed the three-cornered species, which are all American, in one genus, which must therefore be called *Lactophrys.* Of this name *Rhinesomus* is a synonym, and our species should stand as *Lactophrys tricornis.* The fact that *Lactophrys,* as a word (from Latin *lactus,* smooth, Greek ὀφρύς, eyebrow; or else from lactoria, a milk cow and ὀφρύς) is either meaningless or incorrect makes no difference with the necessity for its use.

In 1862, Bleeker undertook to divide these fishes differently. Placing all the hornless species, whether three-angled or four-angled in

Ostracion, he proposed the name *Acanthostracion*, for the species with horns, *tricornis* being the type. But *Acanthostracion* has not been usually adopted except as the name of a section under *Lactophrys*. The three-angled American species are usually set apart from the four-angled species of Asia, and our cuckold is called *Lactophrys tricornis*. But it may be with perfect correctness called *Ostracion tricorne* in the spirit called conservative. Or with the radical systematists we may accept the finer definition and again correctly call it *Acanthostracion tricorne*. But to call it *quadricornis*, or *listeri*, or *maculatus*, with any generic name, whatever, would be to violate the law of priority.

By trinomial nomenclature we mean the use of a second, subordinate specific name to designate a geographic subspecies, variety or other intergrading race. Thus *Salmo clarki virginalis* indicates the variety of Clark's trout, or the cut-throat trout, found in the lakes and streams of the Great Basin of Utah, as distinguished from the genuine *Salmo clarkii* of the Columbia.

Trinomials are not much used among fishes, as we are not yet able to give most of these local forms correct and adequate definitions such as is awarded to similar variations among birds and mammals. Some of these forms will turn out to be real species, while others represent slight individual variations. It will take long study of much material to define these two sorts of subspecies and to separate one from the other. It is easier to preserve and to study birds than fishes and more people are engaged in it. For this reason the fine discrimination of variant forms has been possible much earlier in ornithology than in ichthyology.

STAGES OF VITAL MOTION.

By O. F. COOK,

U. S. DEPARTMENT OF AGRICULTURE.

THAT the organic universe moves, all evolutionists believe; but the opinion is still prevalent that species change only as the result of external influences, and that evolution is thus a merely passive process, a biological malleability or plasticity. What have been termed static theories of evolution are based on this bald assumption that species are normally in a state of rest or constancy, a notion contradicted by every pertinent fact. Motion in the biological field is, indeed, more obvious than in astronomy, since every separate group of organisms becomes different from its relatives, quite independent of external conditions, except as these may influence the direction of progressive change.

Adaptation and Environment.

No direct and causal connection between environment and genetic variation has been demonstrated, in spite of many assertions and theories. It is axiomatic that evolving organisms must vary from where they are, or in characters they already possess; and as continued existence presupposes adaptation to environment, variations often strengthen adaptations, especially since characters favoring the geographical and numerical increase of the species are likewise best fitted for distribution inside the species. In this way it is possible to understand adaptations without the inheritance of 'acquired' characters impressed upon the organism by the environment. Under the static assumption that species normally maintain a stable average each specific difference needs a separate explanation as the result of an external influence, and the preservation of each new variation must be supposed to require the segregation of a new species. To make place for the modified progeny and protect it against admixture it was thought necessary that the parental type be eliminated, a method gratuitously sanguinary and wasteful, since the new character can be much more rapidly propagated by grafting it into the old species than by founding a new species with a single ancestor—a suggestion often quite impracticable. In contrast with the infinite complexity of this theory is the general explanation afforded by the recognition of biological motion, through which species achieve adaptation because they are able to put forth variations in the necessary directions; not because environment causes the variations, nor because the variants are isolated

from their unimproved relatives. Variation is not a consequence of adaptation; adaptation is a result of variation.*

Heredity and variation are not two opposing forces, the one tending to preserve and the other to destroy the specific type; they are two closely adjacent aspects of the single process of organic succession. The permanence of types is not secured by stable or unchanging characters, but by individual diversity or inconstancy, and the consequent power to move in advantageous directions. Organisms are so constituted that the persistent repetition of the same form or character complex is not possible; the supposition of a non-progressive heredity comes from the pre-evolutionary period. Heredity does not oppose variation; evolution is the inheritance of variations, facilitated by cross-fertilization. The causes of variations are also the causes of the accumulation of variations, and of the resulting diversity of species. Variation and cross-fertilization are the means, while selection and isolation are the incidents, of a continuous organic motion. Species are not normally at rest, nor are their motions predetermined by external forces or by internal mechanisms; they are not compelled in *one* direction, but must move in *some* direction, as variation and environment permit.

The Accumulation of Variations.

Static theories are further inadequate because they neglect the fact that change or biological motion is necessary to maintain the vigor and efficiency of the organism. A kinetic theory,† on the other hand, recognizes such motion as normal, and as facilitated by cross-breeding, instead of being hindered. In whatever environment and however propagated, organisms of all types and all categories of complexity are changing or evolving, though with unequal rapidity. Organisms multiplied asexually and thus connected only in simple or linear series make slow progress in comparison with groups in which variations can be distributed through cross-fertilization. The more complex the organic structure the greater the necessity that it be supported, as it were, by many diverse, intergrafting lines of descent. The reasons for this have not been explained, but for purposes of expression it may be ascribed to a special property or requirement called symbasis,‡ served at

* Reactions to environment are often termed 'adaptations,' but the word in this sense is without evolutionary significance because it has not been shown that any non-congenital variation is hereditary.

† 'A Kinetic Theory of Evolution,' *Science*, N. S., XIII., 969, June 21, 1901; 'Kinetic Evolution in Man,' *Science*, N. S., XV., 927, June 13, 1902.

‡ Symbasis signifies etymologically a moving or standing with or together. The similarity of the word to *symbiosis* is perhaps objectionable, but may assist in the appreciation of the distinction between static and kinetic views. Symbiosis means the living together of different species of organisms on terms of

once by variation and by cross-fertilization. To what peculiarities of substance or structure symbasis is due we have as yet no intimation, but the same might have been said of gravitation and many other properties of matter for which names have proved useful, as well as of growth, irritability, and similarly unexplained attributes of protoplasm.

Variations do not appear and are not selected or accumulated merely because of their usefulness or desirability with reference to environment, but useless or even injurious characters may be adopted as a means of evolutionary movement.* Specialization in the sense of extreme accentuation of characters is often harmful and therefore not to be ascribed to adaptation. The influence of natural selection increases with the nicety of adjustment already attained, or as the range of permissible variation is narrowed. Adaptive specializations also commonly imply a narrow dependence on external conditions, and thus give no assurance of permanence for the type; they are more common on the side-twigs of life than on the main branches. Evolution is both accelerated and retarded by narrow selection or segregation; accelerated if the motion be estimated on the basis of a single character; retarded if the organism be viewed as a whole. Normal evolutionary progress does not go forward on the line of a single character, but requires the accumulation of many variations to maintain the structural coordination and functional cooperation of parts. External modifications require less coordination than internal, and are often exaggerated far beyond the requirements of use, and beyond the limits of developmental welfare.†

Organic change and diversity inside the species are necessary and universal, but species and higher organic groups decline and become extinct if their variations become limited to non functional parts and do not provide, as it were, the facilities by which adjustment to changing environment may be maintained. Nevertheless, fitness for the environment is only one aspect of the evolutionary problem; adaptation is an incident and not a cause of evolutionary progress. Results commonly ascribed to selection are due to the normal motion of organic groups. Environment, including natural selection, segregation, isola-

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mutual advantage. Symbasis refers to the fact that organisms exist and make normal evolutionary progress together or in groups commonly called species rather than in simple or narrow lines of succession.

* In Professor Baldwin's most recent and plausible improvement of the static theory the preservation of new characters seems still to be ascribed solely to natural selection. ('Development and Evolution,' p. 156, New York, 1902.)

† 'The Origin and Significance of Spines: A Study in Evolution,' by Charles Emerson Beecher, *Am. Jour. Sci.*, VI., 1–120, 125–136, 249–268, 329–359, 1898. I am indebted to Mr. Charles Schuchert, of the U. S. National Museum, for bringing this able paper to my attention.

tion and other aspects, is a negative and not a positive factor in evolution. Instead of causing biological motion, environment is able only to influence its direction by presenting obstacles to some tendencies of variation while permitting others to go forward.*

Potential Characters.

This separation of evolution from environment is not lessened by the fact that environment frequently determines the existence or degree of expression of characters. The absence of a substance necessary to the formation of a certain color or pigment prevents its formation, as may also the absence of the heat or sunlight necessary for its elaboration. To expect that external conditions should not influence organisms would be to ignore the fact that they grow by what they take in from the outside, and can not build without materials. By being placed under different conditions two individuals can be rendered far more different than they otherwise would have been, but to call these differences 'variations' and then to generalize that variations are caused by environment is simply the old-fashioned fallacy of the undistributed middle.† There is not the slightest probability that the causes which make related organisms different under different conditions are those which make organisms of common origin different under the same conditions. In his paper on 'Nutrition and Selection' Professor De Vries shows that one of the variations of the poppy depends for the degree of its manifestation upon the abundance of food, or is correlated with vegetative vigor. This does not justify, however, Professor De Vries' inference that all characters are so correlated; and that the dependence was not absolute, even in the instance described, was shown when a reversal of cultural methods did not eradicate the character. The same reasoning applied to the human species would discover that some characters appear only among well-fed people, and that such characters are hereditary and persistent, but we are not compelled on this account to infer that all the differences now existing among us have arisen through over-eating.

Unsuspected differences or powers of variation sometimes appear under new environments, but it has not been shown that such potential or latent characters are less congenital, or otherwise less normal

* As explained later on, a result of extreme segregation or narrow inbreeding is to accentuate variation or produce abrupt changes or mutations. It is as though the closing of all except one of the avenues of change compelled abnormal speed in that direction.

† Even under static theories it has been found advisable to distinguish between 'physiological' or 'direct,' non-hereditary variations due to environment, and 'congenital,' 'direct' or 'fortuitous' variations notably hereditary, though doubtfully connected with environment.

in any evolutionary sense. The wonder is not that organisms build differently with different materials, but that they are able to build with the same materials such infinite diversity of form and structure.

Conditions Favoring Evolutionary Progress.

That with adequate materials supplied by abundant food a species would be able to exhibit a larger range of variation, is undoubtedly true, and offers no difficulties in a kinetic theory. The more favorable the conditions or the more successful the adaptation, the more numerous the individuals; also the more extensive would be the manifestations of the variational possibilities of the species, and the more rapid the resulting evolutionary progress. If static theories of evolution were correct numerical increase would not favor evolutionary change because it would diminish the chances of the segregation on which the preservation of variations has been thought to depend.

The most advanced organic types—those which have traveled farthest on the evolutionary journey—are not natives of islands, but of continents. The greatest and most rapid evolutionary progress has not been made among organisms of localized distribution, but among those having facilities for wide dissemination and free interbreeding. Large species move faster than small. Insular species become diverse from their continental relatives mainly because they are left behind by the latter rather than because isolation favors evolution.

Segregation did not denote evolution either in the remote or in the more recent past. As the geological record is followed backward the more generalized types are found to have more generalized distribution, and if in former ages evolutionary changes were more rapid than at present in any particular group this may well be correlated with a period of very favorable conditions permitting the simultaneous existence of vast numbers of individuals in species continuous over large areas. The later subdivision of these generalized types betokens less favorable circumstances which reduced the numbers or otherwise localized the distribution, and thus segregated the new groups. The birds outnumber the reptiles,* the insects the myriapods, the composites the palms. The better the facilities for distribution the more rapid the evolution.

On the other hand the greater the localization and the fewer the individuals the slower the evolutionary progress of a species, and the more uniform the characters. Their supposed constancy leads systema-

* Mr. F. A. Lucas calls my attention to the interesting fact that a similarly accelerated development occurred among the pterodactyls, a second winged group of reptilian ancestry. In the Jurassic and Cretaceous periods pterodactyls attained a rapid and extensive differentiation of genera and families. Likewise the early Eocene mammal types appeared very abruptly and had a very wide distribution.

tists to ascribe specific rank to insular forms differing in details utterly inadequate for the diagnosis of widely distributed continental types. Multiplicity of species does not signify that the land-snails of the isolated valleys of the Hawaiian Islands are in a state of more rapid evolution than other mollusca, but that the characters of these segregated groups are so uniform that systematists can readily define and distinguish them. Many very small species are known, but they are extremely few in comparison with those of larger distribution, and with suggestive frequency they present indications of approaching extinction.*

The Significance of Mutations.

The uniformity of such narrowly segregated groups is the same as that of many of our varieties of domesticated plants and animals, the history of which is also brief. We have, moreover, with these the opportunity of observing the further symptoms of the process of decline.

As though to compensate for the want of access to the normal number of variations, those which occur become more and more striking, and may even be more different from the parent form than the wild species of the same genus are from each other. They have been said, in other words, to 'answer the definition of species.' Professor De Vries has courageously accepted the results of this reasoning and has equipped his new *Oenotheras* with specific names and introduced them to the scientific world as new members of the vegetable kingdom in regular standing, while the description of many other 'De Vriesian species,' is threatened by some of our too-progressive naturalists.

The inadequacy of natural or other forms of selection as an explanation of evolution has become more and more appreciated, and has decreased confidence in the Darwinian idea that species originate by imperceptible gradations, impelled by natural selection. Professor De Vries and his followers argue accordingly that species must originate by definite and abrupt changes, and have set out to search the biological field for instances to support this theory. But if the present interpretation of evolutionary facts and factors be correct the forms described as 'mutations' are not true evolutionary species, either actual or potential. Mutations more fertile than the parent type have not been reported. They do not arise through normal evolution, but are symptoms of debility due to the absence of evolutionary opportunities; they are not parts of an ascending series, but are obviously declining toward extinction. This difference of interpretation well shows the antithesis of static

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*Degeneration and extinction as the result of inbreeding has not been sufficiently considered as an explanation of the dying-out of insular animals protected from competition and other dangers of continental forms. There are, for example, human remains on many Pacific islands uninhabited at the time of their discovery by Europeans.

and kinetic theories of evolution. Under the former mutations have been accepted as genuine examples of the methods by which species are formed in nature, while under the latter they appear as but the dying spasms of small groups of organisms suffering a fatal separation from the life of their species.

Mr. A. F. Woods has kindly brought to my attention an important confirmation of this association of mutation with reproductive debility, namely, that cultural methods calculated to encourage vegetative growth at the expense of reproductive vigor or fertility are also distinctly favorable to the appearance of mutations and of physiological abnormalities such as variegation of foliage. Professor De Vries made *Oenothera* the special object of his study because the frequency of fasciation and other monstrosities seemed to indicate a high degree of structural instability. The abnormality of this class of evolutionary phenomena was not considered. It was inferred instead that the condition of 'mutation' is a somewhat rare and temporary state through which organisms pass at the period of formation of new species, and the failure to find equal 'mutability' in other plants did not prevent the drawing of general conclusions.

Definitions of Evolutionary Stages.

As a summary of the above discussion three evolutionary conditions may be formally distinguished:

1. *Prostholytic or Progressive Stage.*—The prostholytic or progressive stage of evolution is found in large species of wide distribution containing abundant individuals with free intercrossing of numerous lines of descent. There is unlimited diversity or inconstancy of individual characters, and variation is indefinite and continuous in the sense that endless fluctuations and intergradations are present. The requirements of symbasis are fully met; interbreeding is normal and reproductive fertility is high.

2. *Hemilytic or Retarded Stage.*—The hemilytic or retarded stage of evolution is reached in species or subordinate groups of restricted distribution containing a limited number of individuals with few and closely interrelated lines of descent. Characters are nearly uniform and variation slight. The requirements of symbasis are not fully met, but the deficiency has not yet resulted in reproductive debility.

3. *Catalytic or Declining Stage.*—The catalytic or declining stage of evolution appears in closely segregated groups of relatively few individuals propagated by inbreeding or on single lines of descent. Variations are few, pronounced, and abrupt or discontinuous, also relatively constant and with little or no intergradation. The catalytic stage implies a violation of the law of symbasis, or inadequate cross-fertilization, together with the resulting deficiency of fertility.

Effects of Inbreeding.

These stages or states of evolution are distinguished and named in the belief that they will afford a useful addition to our evolutionary vocabulary. They are, however, parts of a connected series of events with no lines of separation between them. All organisms which too close segregation has brought to the catalytic stage have passed through the hemilytic. For example, the recently domesticated pecan tree of our southwestern states is still in the first or normal stage of evolution, and only a small proportion of the seedlings produce nuts like those of the parent tree. Selective inbreeding for a few generations would first produce uniformity, or 'fix the type,' as the expression is, by inducing the hemilytic or retarded stage of evolution, while a too narrow and persistent selection or the segregation of a single line of descent would hasten the decline and eventual destruction of the very type it might be designed to perpetuate. Coffee has not been domesticated for much more than a thousand years, and although selection has not been practised, very pronounced and constant variations are now appearing in considerable numbers, but all less fertile than the parent stock. That inbreeding tends to 'fixity' of characters is true only for a time; organisms in the catalytic stage are rendered less uniform as well as less fertile by continued inbreeding. Uniformity and vigor can be restored, as breeders already know, only by the repetition of the process of selective segregation after cross-breeding with another stock.

The catalytic stage is attained more slowly by asexual propagation, and the variability is far less pronounced, but partial or complete sterility has appeared in a considerable series of unrelated tropical plants long propagated only by cuttings, such as the banana, pine-apple, sugar-cane, sweet-potato, Irish potato, taro and yam.

Parthenogenesis may also be viewed as a form of asexual propagation, and habitual self-fertilization is another stage of sexual and evolutionary decline. Self-fertilization is supposed to be normal in several of the cereal grasses and in many other plants, though it is obviously unsafe to infer that cross-fertilization is entirely superfluous because frequently absent. With the cereals and other plants of similar history self-fertilization may prove to be a result of cultivation in northern latitudes where the weather is often unfavorable for pollination by the wind or by insects, so that selection would encourage variations least dependent upon cross-pollination. I learn from Mr. Jesse B. Norton that the more primitive, hardy, and disease-resistant oat varieties of South Europe open their glumes widely and thus invite cross-fertilization, while in most of the varieties bred in the colder and more rainy climate of Northern Europe the glumes separate much less, and do not expose the stigmas, thus showing that cross-fertilization has been abandoned. Darwin proved that there is no benefit in the cross-

ing of closely related individuals, as distinguished from fertilization by the pollen of the same flower, and since domestication implies inbreeding the habit of self-fertilization would involve no additional injury, but would have an important practical advantage in greatly increasing the chances of pollination and seed-production.

Mutations and Hybrids.

The recognition of symbasis, or the necessity of a broad foundation to sustain the organic structure, permits the inference that some hybrids are sterile and variable for the same reason that closely inbred plants and animals decline in fertility and produce mutations or deviations from the normal type. A hybrid is a mixture or cross between individuals which would not be expected to mix in nature. Among domesticated plants hybridization signifies the reverse of selection, the crossing of varieties which the breeder commonly strives to keep separate. Generalizations to the effect that hybrids as a whole are sterile, variable, weak or vigorous are fallacious, since the results of the crossing depend upon the evolutionary status of the parents. By segregation or inbreeding normal or progressive variation gradually gives place to uniformity and then to mutation, but hybrids between distant types pass at once from the progressive stage to the catalytic. On the other hand, crosses between inbred or closely segregated stocks may show increased vigor and stability, and thus reverse the process of decline. Hybrids, therefore, may be either prostholytic or catalytic as they tend upward or downward in the evolutionary series.

Diagram of Evolutionary Stages.

Cross-breeding.	Sterility.	
	Catalytic or declining stage.	Aberrant or mutative hybrids.
	Dialytic or divergent stage.*	Mendelian hybrids, characters antagonistic.
Symbasis.	Prostholytic or progressive stage.	'Inconstancy' with intergradations, as in natural species.
Inbreeding.	Hemilytic or retarded stage.	Uniformity or 'fixed' types.
	Catalytic or declining stage.	De Vriesian mutations or 'sports.'
	Sterility.	

Cross-breeding and close-breeding have the same limits of sterility; and between each and the mean of normal evolution there is, as shown by the experiments of Mendel, Garton, De Vries and others, a region of the relatively infertile abrupt variations variously termed sports,

* The dialytic or divergent stage might be described as the reverse of the hemilytic; it is characterized by the facts discovered by Mendel, Spillman and others, which may be taken to signify that the characters upon which close-bred varieties have diverged do not combine into an average in the hybrid offspring, but remain antagonistic and follow one or the other of the parental lines.

mutations and hybrids. The weakness and sterility of too distant crosses and of too closely isolated or inbred plants or animals may be due alike to a deficiency of normal fertilization, and may be accepted as evidence that the true course of evolution lies along neither of these extremes but follows the natural mean between them.

Discontinuous Variation.

Catalytic variations have not the indefinite number and diversity of the progressive stage; like the symptoms of other disorders of plants and animals the same or closely similar mutations recur in somewhat definite proportions, and are not peculiar to single species, but many members of a genus or family may be similarly affected. It is therefore not necessary to interpret the independent repetition of the same symptom of evolutionary debility as an evidence of the inheritance of definite character complexes or units.* The truly admirable but often misinterpreted experiments of Mendel did not result in the discovery of 'principles of heredity' so much as they revealed limits of hybridization, in that hybrid plants were found which inherited the characters of only one parent. The failure of strongly divergent or antagonistic characters to combine into a permanent average in hybrids gives, however, no basis for denying that normal evolution proceeds by the synthesis or accumulation of acceptable variations, nor is abrupt or discontinuous variation in individuals in any way incompatible with the probability that in nature evolution goes forward only through the gradual transformation and subdivision of species. The emphasis placed by Bateson, De Vries and others upon abrupt variations is warranted by no general pertinence of the facts, and is but a consequence of the failure to perceive that the origination or multiplication of species is an incident rather than an instance of evolution.

Cross-fertilization Accelerates Evolution.

Organic succession will not persist on too narrow lines of descent, does not normally leap aside from its course, and will not bridge over too broad a chasm of evolutionary divergence. Amount of difference in the external characters of two groups affords little indication regarding the behavior of their hybrids. Some groups treated by the systematists as closely related species will not even hybridize, while in other instances plants assigned to different genera are mutually fertile. Such discrepancies are doubtless due partly to inadequate classification and partly to the fact that organic evolution is attended also by a cytological or cellular evolution the progress of which may not be con-

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* Criminologists have found in the human species the same tendency of abnormal individuals to fall into recognizable types. Inbreeding is also recognized as a frequent cause of aberrations from the mental and physical average of the race, just as sterility and emotional abnormality are among the most frequent phenomena of criminality.

sistently uniform. That the cytological or cellular evolution is commonly slower than that which affects external characters seems probable because domesticated plants and animals more different than mutually sterile wild species are still completely fertile. That all the types produced under domestication from the same wild species hybridize freely, and thus do not have the stability and isolation of natural species, was frankly admitted by Darwin and Huxley as 'one of the greatest obstacles to the general acceptance and progress of the great principle of evolution,' and it is no less an obstacle to the acceptance of the complicated and self-contradictory static theories formulated as alleged improvements of the views of these evolutionary pioneers. If, however, evolution be recognized as a kinetic process this fundamental difficulty completely disappears, since the cross-fertilization which hinders the segregation of species is not on this account an obstacle to evolution, but is, on the contrary, the most important agency for the acceleration of vital motion. By overlooking this fact builders of evolutionary theories have continued, as it were, to stumble over the corner-stone of the biological structure.

THE SLAVIC IMMIGRANT.

By Dr. ALLAN McLAUGHLIN,

U. S. PUBLIC HEALTH AND MARINE HOSPITAL SERVICE.

EVERY new factor of our immigration is looked on with suspicion. It is the right and duty of every American to criticize justly the raw material for future citizenship passing within our gates and to insist that this material shall be measured and weighed, measured by the standard of humanity, weighed in the scale of justice, and if found wanting sent back without ceremony or sentiment whence it came. But too often the criticism is blinded by race prejudice and ignorance of the immigrant. Every race that has figured prominently in our immigration statistics has had to bear the brunt of attacks by well-meaning pessimists, who, in many instances, never saw an immigrant in the rough. In this regard the Slav is not more fortunate than his predecessors, the German, the Irishman and the Scandinavian.

One of the most striking facts shown by recent immigration statistics is the rapid increase of Slavic arrivals. From almost nothing before 1868, it has grown progressively year by year, until it now constitutes nearly one fourth of our total immigration. In view, therefore, of the fact that the desirability of Slavs as immigrants is in question at the present time, and that they constitute such a large proportion of our total immigration inflow, a consideration of the Slavonic immigrant seems pertinent.

Eastern Division.	1. Great Russians. 2. Little Russians. 3. White Russians.
Balkan or Southern Division.	1. Croats. (*a*) Croatians. (*b*) Slovenes. 2. Serbs. 3. Bosnians. 4. Montenegrins. 5. Bulgars.
Western Division.	1. Poles. 2. Slovaks. 3. Czechs. (*a*) Bohemians. (*b*) Moravians. 4. Lusatian Wends.

The Slavic race may be conveniently divided into three great divisions according to their geographical distribution in Europe: an eastern division, embracing all the Russian Slavs; a southern division, the Slavic inhabitants of the Balkan states, and that portion of Hungary

south of the Danube; and a western division, comprising those Slavic peoples whose progress westward in Europe has formed a Slavic wedge, separating the Germans of upper and lower Austria from the Germans of Saxony and Brandenburg. The above table indicates a simple geographical classification.

The unshaded portion of the map shows the territory in Europe occupied by Slavs.

Since of the many subdivisions given in the preceding table only fivė furnish us with more than one thousand immigrants a year, and since these five races aggregate ninety-seven per cent. of the total Slavic immigration, a consideration of them practically covers the whole field. The following table shows the numerical strength of the Slavic arrivals for the year ended June 30, 1902.

Poles	69,620
Slovaks	36,934
Croats	30,233
Ruthenians	7,533
Czechs	5,590
All other Slavs including Russians, Bulgars, Serbs, Montenegrins, etc.	5,879
Total Slavs	155,789

The Poles.

The lot of the Polish peasant has always been unhappy. When Poland at the zenith of her power ruled White Russians, Ruthenians

and Lithuanians, when her dominion extended from the Oder to the Don and from the Baltic to the Black Sea, the position of the Polish serf was as unenviable as it is to-day. Poland was an oligarchy in which the ruling nobles and their miserable serfs had no bond of sympathy. There was no Polish middle class to carry on commerce and trade, to serve as a connecting link between the two widely separated classes. Commerce and trade were in the hands of foreigners, chiefly Jews. The Pacta Conventa (1572) or, as it has been called, the Polish Magna Charta, was in no sense a charter of the liberties of the people. It is true that it curtailed the power of the king and made him a mere figurehead, but it greatly increased the power of the nobles and, if anything, added to the misery of the peasants. These conditions made impossible a universal national feeling, and paved the way for Poland's downfall.

No doubt Russian treatment of Polish landowners and nobles has been unjust, even cruel, but it must be remembered that the first real freedom the Polish serf ever enjoyed he received from his Russian masters. Russia abolished serfdom and, after the Polish insurrection of 1863, the Czar sought to conciliate the Polish peasant class by certain agrarian reforms. By these measures the peasants settled upon land and were made owners, the government compensating the landlord and exacting from the peasant a small sum yearly until the amount advanced was paid. Following the suppression of the revolt, wholesale confiscation placed upon the market thousands of acres of good farming land, and in a great measure broke up the large estates which kept the peasant a serf, even after he was declared free. Unfortunately for the Polish peasant, he was usually too poor to buy any of the land thus placed in the market.

But the conciliatory policy of Czar Alexander II. is not favored by the present ruler. His efforts at Russification are aggressive and persistent. It is to America that the Pole looks as the only land likely to give him a chance. The Polish immigrants possess the general characteristics of the Slavs. They are of medium height or very slightly below it, very strongly built, with the broad face and brachycephalic head of the Slav type. Their complexion shows all gradations from the blue eyes and light hair in the Slavs of the north to the pronounced brunette type of the southern Poles. Five sixths of the male Polish immigrants are unskilled laborers. They are very willing to work and are especially useful in the mines, mills, manufacturing concerns and great works of construction.

The geographical distribution of Poles arrived in America during the year ended June 30, 1902, is shown below:

State	Number of Poles.	Ratio to Total Poles Landed.
Pennsylvania	21,929	32 per cent.
New York	14,364	21 "
Illinois	8,818	11 "
Massachusetts	5,916	8 "
New Jersey	5,689	8 "
Connecticut	3,299	5 "
Ohio	2,502	4 "
Michigan	1,899	3 "
Wisconsin	1,059	2 "
All other states	4,225	6 "
Total	69,620	100 per cent.

The Slovaks.

There are two factors that more than any others tend to preserve the purity of a race. They are the inaccessibility and the uninviting nature of the country it inhabits. Thus, races occupying a barren mountainous country or a country covered by trackless forest and impassable marshland are apt to be of purer racial type than the races living upon the great natural highways of commerce and trade or occupying territory rich enough to be inviting to covetous eyes. These factors have had much to do with the preservation of the purely Slavic type as represented by the Slovaks. This people occupies the rough mountainous country on the Hungarian side of the Carpathians, well back from the valley of the Danube.

The Slovak is very closely allied racially to the Bohemian or Czech. Their languages are similar, the Slovak being the more primitive and more like the old Slav. Up to the beginning of the nineteenth century, the Slovaks used the Bohemian language for all printed or written forms, but about that time a separatist movement began and an effort was made to develop a Slovak literature. This movement was unfortunate for both Czech and Slovak, because they had to resist the same natural enemies—aggressive Pan-Germanism on the one side, and the ever-intrusive Magyar on the other.

Physically, the Slovaks are a sturdy stock, a little taller than the Poles. The great majority of the men are unskilled laborers. The following table indicates how the Slovaks were distributed for the year ended June 30, 1902:

State.	Number of Slovaks.	Ratio to Total Slovaks Landed.
Pennsylvania	19,930	54 per cent.
New York	4,904	13 "
New Jersey	3,479	9 "
Ohio	3,153	9 "
Illinois	2,114	6 "
Connecticut	1,025	3 "
All other states	2,332	6 "
Total	39,934	100 per cent.

The Croats.

The Croatians and Slovenes occupy the two large provinces to the south of Hungary, Croatia and Slavonia, that lie between the Drave and Danube rivers on the north and the Save River and the Bosnian boundary line on the south. A large number of the same race also come to America from the adjoining provinces of Carniola, Carinthia, Styria, Istria and Dalmatia.

Croatia and Slavonia formed part of ancient Pannonia. The Slavs took possession about the seventh century after Ostrogoth and Hun had come and gone. They recognized the authority of the Emperors of the East until 1075, when their leader, Zwonimir Demetrius, threw off the Byzantine yoke and received the title of king from Pope Gregory VII. at Rome. The country was subdued by the Turks (1524) and, from the time of their expulsion some years later, has been considered a part of the Kingdom of Hungary. The Croats took sides against the Magyars in the revolt of 1848, and Austria rewarded them by making them independent of Hungary, but in 1860 Austria's attitude changed, and to conciliate the Magyars she restored them to Hungary. They are not content. Their national feeling is intense, and, though loyal to the house of Hapsburg, they desire complete autonomy, with the Emperor of Austria as their king. They detest their Magyar rulers, and there exists as a consequence a constant clashing of Magyar and Slav throughout the provinces. This race of southern Slavs presents some peculiarities when compared with the recognized Slav type. They are dark-eyed and swarthy skinned (very different in complexion from the northern Slavs). Their heads are brachycephalic, not so much from great width as from a very short antero-posterior diameter. This peculiarity is striking if the subject be inspected in profile. The line of contour from the vertex of the skull to the root of the neck is almost perpendicular. Compared with the average Pole or Russian, who is not above medium height, they are very tall. Their stature is remarkable not only because it is so unlike that of the typical Slavs, but also because it is an exception to the general rule that European races are tall in the north and short in the south.

The Croats are of slighter build than Pole or Slovak, but they have fewer physical defects than any other Slavic people.

More than seven eighths of the males are unskilled laborers, strong and willing to work. The table given below shows how they were distributed in the United States during the year ended June 30, 1902:

State.	Number of Croats.	Ratio to Total Number of Croats Landed.
Pennsylvania	16,726	56 per cent.
Illinois	3,547	11 "
Ohio	2,923	10 "
New York	1,651	5 "
All other states	5,386	18 "
Total	30,233	100 per cent.

The Ruthenians.

The statement that nearly all Russian immigrants in America come from Austria may seem strange, but it is true. Last year 7,540 Russians came from Austria and only 1,536 Russians from Russia.

The Russian Slavs are divided by philologists into three divisions: Great Russians, White Russians and Little Russians. The Great Russians occupy a large quadrangular area in Russia consisting of the central governments, from Novgorod and Vologda on the north to Kiev on the south; from Pensa and Simbirsk on the east to the Polish provinces on the west. The White Russians number less than four millions and occupy some of the western governments adjoining Poland. Great Russians and White Russians do not emigrate. The Little Russians occupy the great fertile treeless plain, the black mold belt in southern Russia, which extends from Kiev to the Black Sea. They also people the two Austrian provinces of Bukowina and Galicia. It is said that a line drawn eastward on the map from Cracow in Galicia through Kiev in Russia will divide the Little Russians from the Great Russians. The Little Russians occupying Galicia and Bukowina, Austria, are known as Ruthenians. They are also called Russniaks and Red Russians. Nearly all our Russian immigrants come from these two Austrian provinces. The Ruthenians are typical Slavs. They have a rugged, sturdy physique, and the men are almost all unskilled laborers. They were distributed in America as follows, during the year ended June 30, 1902:

State.	Number of Ruthenians.	Ratio to Total Number of Ruthenians Landed.
Pennsylvania	4,153	55 per cent.
New York	1,594	21 "
New Jersey	746	10 "
Ohio	328	4 "
All other states	732	10 "
Total	7,533	100 per cent.

The Czechs.

From within the boundaries of the kingdom of Bohemia and the adjoining province of Moravia come each year several thousand immigrants of Slavic blood. There is little difference racially between the Bohemian and Moravian and they are usually classed together as

Czechs. Bohemia constitutes the point of the wedge formed by the advance of the western division of the Slavic race into Central Europe. For this reason Bohemia has been the bulwark of Slavic supremacy, and has acted the part of a buffer in checking the progress of pan-Germanism in the Slavic states. The German element is stronger in Bohemia than in any other Slavic state, and the Bohemian Slavs are taller and more blond, possibly because of a strong infusion of Teutonic blood.

The Czechs possessed a native literature as early as the ninth century. Their country is well supplied with schools, in about one half of which the Czech language is spoken. They are far better educated than any other Slavic immigrants.

The valley of the Elbe is a rich agricultural country, and throughout the kingdom industry and manufacturing are highly developed. For this reason more than fifty per cent. of Czech immigrants are skilled laborers or mechanics—an unusually high percentage for Slavs.

The Czechs have a very wide area of distribution in this country. This is natural, for, being skilled in various occupations, they can find employment anywhere. They have scattered from New York to Nebraska and Texas. The following table shows the destination by states of the Czechs arrived last year:

State.	Number of Czechs.	Ratio to Total Number of Czechs Landed.
New York	1,387	25 per cent.
Illinois	1,375	25 "
Ohio	660	12 "
Pennsylvania	571	10 "
Texas	391	7 "
Wisconsin	217	4 "
Nebraska	194	3 "
All other states	795	14 "
Total	5,590	100 per cent.

There are certain cardinal requisites in the make-up of a desirable immigrant. He must have a good physique, he must be willing to do rough hard labor, and he must be a man who intends to make this country his permanent home. Observations of the Slavic immigrants will show that they have a very rugged physique, that they are very willing to work at the most arduous labor, and that they have no desire to return to the oppression and grinding poverty of the old world. A dispassionate study of their history in Europe reveals nothing to their disadvantage. In addition their moral standard is a very high one. They are a simple, right-living people, intensely religious and mindful of family ties. They are guileless compared with the Hebrew, Italian or Levantine races, and before the Board of Special Inquiry they usually tell the plain truth.

The demand for rough unskilled laborers has steadily increased with our wonderful industrial growth. It is generally admitted that this demand cannot be supplied by native American applicants. Of all foreign laborers none is better qualified for this work than the Slavs. Eighty-five per cent. of the male Slavs are unskilled laborers, and nearly ninety-five per cent, come to this country between the ages of fifteen and forty-five, when their economic value is greatest.

These people do not crowd the tenements of our large cities, but tend to establish themselves in little homes of their own in the country or in the suburbs of manufacturing towns and cities.

The Slav is popularly supposed to be mentally slow and without energy or ambition. This is not entirely true. In comparison with the Hebrews who transact nearly all the business in Poland and Galicia, the Poles (in business acumen) seem as children. The Slovak appears mentally slow compared with the alert Magyar, but it must be remembered that the Hebrew in business makes other races than the Slav seem slow, and that, while almost all Magyars can read and write, one third of the Slovaks are illiterate. This seeming mental deficiency and absence of ambition in the Slav is due mainly to lack of education and to centuries of subjection to tyrannical masters. It is hard to conceive how a peasant in Russia under existing conditions could develop such a quality as ambition, and judgment as to the Slav's energy and his intellectual possibilities must be suspended until his children in this country have had a chance to show that American schools and American environment can quicken the slow apathy of the serf into the energetic activity of the freedman.

The Slavic immigrant fills a place in the industrial fields of this country in which he hears no call for such attributes as ambition, energy and mental brilliancy, a place which no American envies him, and where he is as necessary to American advancement as the coal and iron that by his labor are mined and made ready for the American mechanic and manufacturer.

OBITUARY NOTICE OF A LUNG-FISH.*

BY PROFESSOR BASHFORD DEAN,

COLUMBIA UNIVERSITY.

THERE died recently in the aquarium room of the department of zoology of Columbia University, a specimen of the African lung-fish, *Protopterus annectans*. Here it had lived for nearly five years, thriving at the cost of generations of living earthworms and increasing in size nearly three-fold. From the fact that this interesting fish is relatively rare in aquaria, the present specimen is possibly deserving of a formal memorial notice.

It arrived at Columbia University in July, 1898, in a sun-baked clod of earth, in which under native conditions the fish lies dormant during the summer drought. In this state it had been living for several months, and during the interval it had been breathing air, thanks to its lung, in a very unfish-like way. Its earlier history may be written

FIG. 1.

FIG. 2.

CLOD OF EARTH CONTAINING COCOON OF LUNG-FISH. Fig. 1 shows entrance burrow, Fig. 2 remains of cocoon after escape of fish.

with tolerable accuracy. Its early life was spent in some African stream in the region of the Congo, where it had lived successfully

* The lung-fish is generally regarded as a little modified survivor of the ancient 'connecting link' between the water-living fishes and the air-breathing and four-legged amphibians. There is the clearest evidence that in the early geological periods the lung-fishes represented a flourishing stock both in numbers and kinds. At the present day they are reduced to three genera, one Australian, one South American, and one African.

hunting and unsuccessfully hunted, until the approach of the dry season. Then as the stream dried up, it had taken to the last pool, and when this in turn had dried, the fish, like its neighboring friends and relatives, had burrowed deep into the thickening mud, rolled itself up into a ball, secreted a mass of mucus about its coiled body, and made ready for a summer 'sleep.' One of its first precautions was to keep its nose uppermost and to see that its 'breath' found a passageway out of its slimy capsule into the open burrow: in this way, then, it could breathe throughout the summer, while awaiting dormantly the return of rains, and the melting of its 'cocoon.' In this stage in its history it came to be dug up, and, together with other cocoons and their surrounding clods of earth, was crated and shipped to Europe. I am told that the shippers take pains to surround the crate with iron gauze to preserve the fish from the attacks of rats on shipboard, and that the clods of earth are disposed in such a way that the sides containing the breathing apertures face outward so that the imprisoned fish run the least possible danger of becoming stifled.

The present shipment came into the hands of Professor H. O. Forbes, Director of the Public Museums of Liverpool, and through his kindness the present specimen was donated to Columbia. A photograph, Fig. 1, shows the cocoon just as it came to the present writer. The tubular burrow through which the fish worked its way into the mud is seen conspicuously, and one may note that it was somewhat crooked, in spite of the fact that part of its margin has been broken away in the present specimen. Its usual length appears to depend upon the character of the bottom; from two to five inches are the measurements stated. At the end of the burrow lies the cocoon, a roundish mass, brown in color, paper-like in texture, but greatly roughened on its outer surface by attachment to rootlets and foreign matter. Its inner surface, as one would expect from the mucous nature of the shell, is found to be smooth and delicate. Where the cocoon meets the outer burrow its shell is somewhat flattened, and here, near the side, it is perforated by a delicate straw-like tube, formed of dry mucus, which passes downward into the mouth of the fish, and through this the fish respires during the dry season. It has, indeed, been shown by Professor W. N. Parker that this tube passes within the mouth of the fish and conducts the air to the entrance of the fish's lung.

In liberating the fish from the cocoon, the usual procedure is to allow the mass to remain in warmish water until the earth softens and melts, but in the present case a shorter, but somewhat more perilous, course was adopted. One side of the block was cautiously sliced away until the side of the papery cocoon became visible: then the earthy margins of the opening were carefully removed, so that the process of liberating the fish could be observed. The entire mass was next

placed in an aquarium in water slightly warmed. In a few moments slight movements of the fish could be seen through the papery shell; and upon lifting out the earthen block and touching the cocoon, a distinct croaking sound was heard several times. Replaced in water, the capsule soon softened and ruptured like wet paper, and for a moment a glimpse was had of the fish tightly rolled up, with its tail folded over the head and only a single thread-like limb protruded. This, however, was but for a moment, for with an energetic squirm the animal liberated itself and sank to the bottom of the aquarium. For a moment it lay motionless, then swam briskly around the aquarium, coming to the surface several times and gulping air. At this time it showed the crimson flush of blood in the tail region where, according to Wiedersheim, the skin aids the lung as a respiratory organ. The fish, as one might indeed have inferred from the size of the burrow in the clod of earth, proved to be small, measuring a little over five inches in length. It was, however, larger than one would have estimated from the diameter of the tubular opening and from the actual size of the cocoon, the latter measuring about two inches in length and one inch in thickness. In Fig. 2 is shown the remains of the cocoon after the escape of the fish, the upper portion of the papery case alone being preserved.

From the small size of the fish this was possibly its first season of æstivation. How long it had been out of the water was not known, but

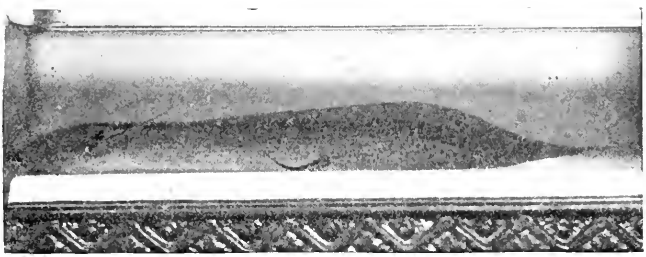


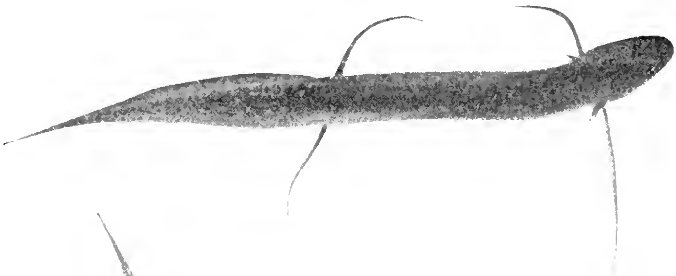
FIG. 3. LUNG-FISH, *Protopterus*. Resting position in aquarium.

certainly this was a matter of several months. I have, indeed, learned from Dr. Forbes that a fish will sometimes survive a period of eight months out of water.

Shortly after its release from the cocoon the writer's colleague, Dr. Edward Leaming, took a number of photographs of the fish, some of which are shown herewith, to give a graphic idea of its appearance and unfish-like movements (Figs. 3 to 6). In side view, Fig. 3, the fish is shown in a position of rest, its body resting upon the bottom, its long, paired extremities extended out, braced against the glass side of the aquarium. When moving, however, the fish would

lift its body by means of the paired fins, and these would then serve after the fashion of the arms and legs of a quadruped as the fish 'walked' slowly about, alternating the forward and backward movements of its extremities. This condition is illustrated in Fig. 4, in which the bend of the arms and legs, where they support the weight of the fish is shown satisfactorily. In this figure, which, together with Figures 5 and 6, were photographed from almost directly above the fish, one observes that the strain upon the limbs falls, not upon their

Fig. 4.



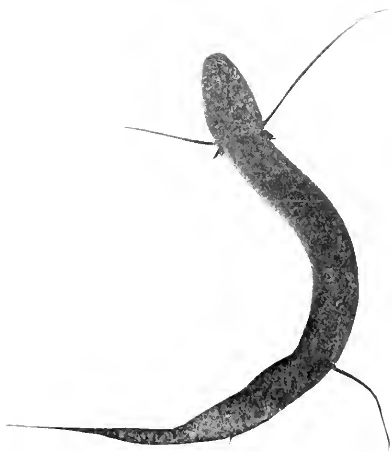


Fig. 5. Fig. 6.

Lung-fish showing Various Movements.

tips, but near the middle. Thus one notes in Fig. 6 that the tip of the right-hand pelvic limb curls upward and is free from the bottom. One observes especially in Fig. 3 the stress upon the left pectoral limb, which causes it to be bent almost at right angles in an elbow-like fash-

ion. This limb, by the way, has lost its tip, and is being regenerated, the lighter portion, as shown in the figure, having already been grown. I might note that at the point where the injury occurred a small transverse branch later made its appearance, but after this had grown for a year or two and become one eighth of an inch in diameter, it gradually degenerated and finally entirely disappeared. A characteristic movement is illustrated in Fig. 5; here the fish, having reached the end of the tank, draws back before turning in another direction. To accomplish this result, the fins again operate in a quadrupedal fashion: pressing on the limbs firmly, the fish recoils, pushing itself back by means of its shoulder and pelvic muscles, the tail and body taking little or no part in the process. In this figure we again note the strain which is laid upon an extremity, for the left arm is bent almost to the shoulder.

Another characteristic movement is pictured in Fig. 6, where the animal is circling around. The weight of the hinder body is supported firmly by the outstretched legs, and the arms swing forward and backward, turning the anterior part of the body. In the present position the animal is on the point of again advancing, and in this event the limbs will move alternately as shown in Fig. 4. Throughout these varied movements the fish is slow and deliberate, reminding one rather of a newt than of a fish. In the present figures attention should be called to the great length of the uninjured arm, which in this small specimen indicates doubtless a larval feature of the fish. Also noteworthy is the position of the external gills, which stand out at the sides of the head very much as they do in a larval salamander.

From this stage onward the life of the lung-fish was a rather uneventful one. It received its daily diet of earthworms with apparent relish, and upon them it thrived and grew. Its yearly increase in size varied between two and three inches; at the time of its death it measured eighteen inches. Its movements in the aquarium were like those of larval salamanders, axolotl, for example. Only on rare occasions did it swim in a fish-like manner by means of caudal fin and undulating body, and only twice a year did it show of what sudden movements and great activity it was capable. On these occasions it was taken from the tank and carried to or from the New York Aquarium where, through the courtesy of the officials, it was kept during the summer. Cold weather, as might be inferred, it was least capable of enduring. On several occasions during winters, when the temperature in the aquarium room became less than 50° F., the fish was found in a semitorpid condition. It was then taken out and handled with scarcely a movement, but was revived by immersion in warm water. It gave its attendant no uneasiness on the score of appetite, for it took its food with clock-like regularity. Its great difficulty, however, appeared

to be due to defective eyesight, for even though a moving worm were put in its immediate neighborhood, the fish did not appear to detect its presence through the sense of sight. At first, stimulated probably through its lateral line system, the fish seemed to feel the movements of the earthworm; it would then turn in the direction of the food, move towards it with apparently increasing enthusiasm, but when only at close range did it seem actually to see the prey. The fish's movements in feeding reminded one rather of a turtle than of a fish, or, best of all, of its kindred salamanders. Eyeing the moving worm steadily, it would make a sharp snap at it. If this movement failed, it would appear to deliberate, gaze fixedly at the object, and snap again. If more successful this time, it would pause with the food in its mouth, then with a series of accelerating snaps, the entire worm would be ingested. Occasionally a worm would be cut entirely in two by the quick snap of the fish's powerful jaws, and this would result in the

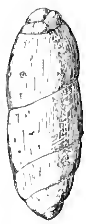


Fig. 7 *a*.

Fig. 7 *b*.

Fig. 7 *c*.

loss of the worm and in the feeding beginning anew. During this entire process the fish's arms would be spread widely apart, so as to support the weight of the head.

In later years the fish became quite tame, and would feed out of the hand of the laboratory attendant, who always maintained that the fish distinguished him from other visitors. Certain it was that he finally accustomed the fish to a diet of raw meat, and this substitute for earthworms proved a convenient one during the cold season. A finger thrust into the aquarium and stirred vigorously would be enough to attract the fish's rather sluggish attention: it would slowly leave its resting place, 'walk' toward the region of the disturbance, rise to the surface and after giving the usual evidence of bad eyesight would finally get its mouthful of food. The fecal material of the fish, one might mention, showed the cast of the spiral intestinal valve which in lung-fishes is almost as well developed as in sharks. Possibly, there-

fore, some of the coprolites from early geological horizons which have generally been referred to sharks may have belonged to contemporary lung-fishes. The fecal material at the time it is deposited appears as in Fig. *7a;* after remaining in the water for several hours it presents the appearance *7b,* and finally, after twenty-four hours, uncoils as in Fig. *7c.*

The air-breathing movements of the fish were irregular. At times it would come to the surface about every five minutes and swallow a mouthful of air; then again several times this period would elapse before the fish would rise to the surface. In all cases escaping air passed out through the gill clefts, usually through those on the left side.

THE OPPORTUNITY OF THE SMALLER MUSEUMS OF NATURAL HISTORY.

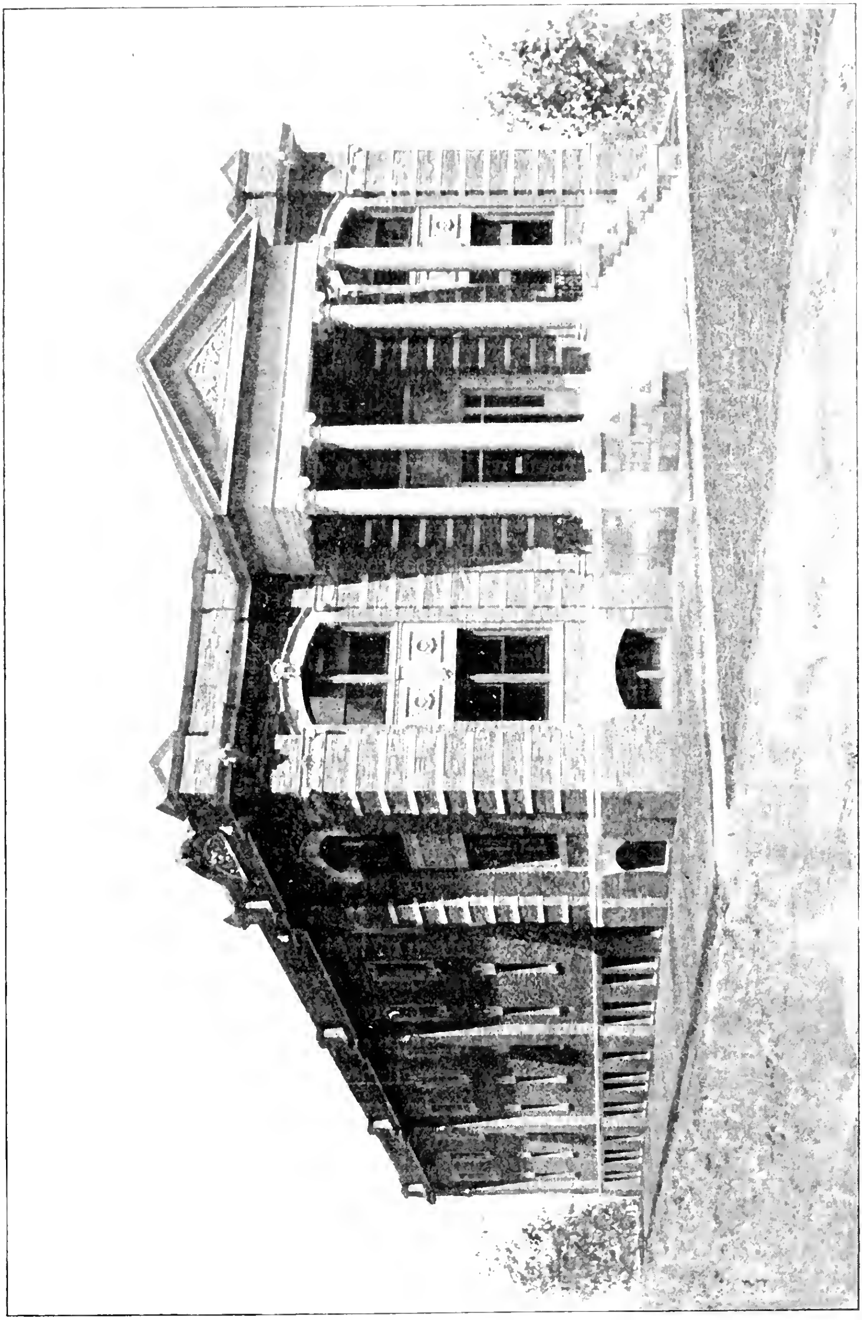
By WILLIAM ORR,

SPRINGFIELD, MASS.

WITH the rapid growth of public libraries and the multiplication of books, periodicals and newspapers, there has arisen an urgent need for the direction of popular reading and for the promotion of serious study. Librarians are striving, with the aid of schools and teachers, to counteract the general tendency towards aimless superficial reading. Another educational agency that promotes exact knowledge, quickens observation and leads to research and consecutive study is the museum of natural history.

The near future may well see as great an interest in the establishment of museums as there is now in the founding of libraries. Such an institution can do an especially valuable service in the smaller city or town, provided its directors sense and seize their peculiar opportunity and clearly recognize the limitations imposed by local conditions. There should be no attempt to imitate the expensive buildings, exhaustive synoptic collections and the elaborate research and exploration of museums in the great centers of population. Salaries and incidental expenses can be kept at modest figures. Volunteer workers should be enlisted to cooperate with the paid officials. Public interest and the practical support of men of means are important factors to secure and retain. Connection with the public library under one general management makes for efficiency and economy.

For distinction and reputation the small museum must depend on special excellence in a few departments, on its representation of the local natural history and on its influence as an educational force in the community. Large sums may be spent to advantage on groups or on individual specimens when by such features local pride is aroused and visitors attracted. Carefully selected index collections can be used to give general views of the animal, plant and mineral worlds, while industry and ingenuity find full room for exercise in illustrating clearly and vividly the geology, botany and zoology of the region in which the museum is situated. As an agent of popular instruction the museum in the smaller centers possesses important advantages in the comparative ease with which people may be reached and interested. Usually the tone of life and the freedom from distracting influences are favor-



SCIENCE BUILDING, CONTAINING MUSEUM OF NATURAL HISTORY AND CATHARINE L. HOWARD MEMORIAL LIBRARY OF SCIENCE.

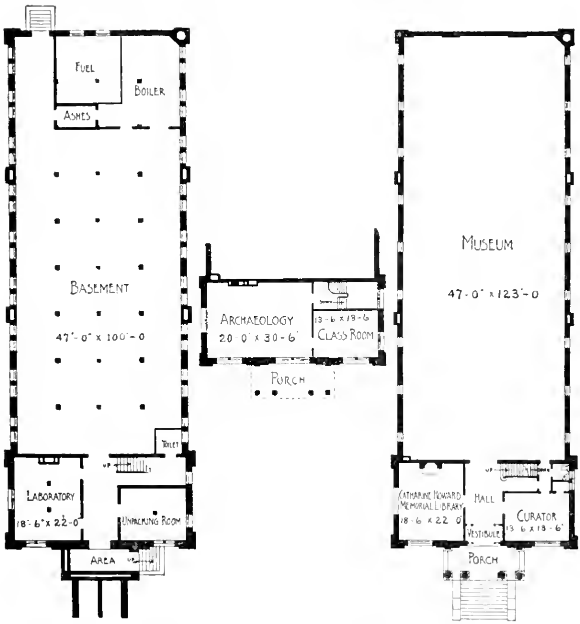
able to earnest study. Adequate moral and financial support are assured by the promotion of a general interest in the museum. The open country is accessible for excursions by various scientific societies. Rambles are a delightful means of leading girls and boys to a knowledge of the treasures of nature in the hills and valleys near their homes. Even in the village, much may be done to relieve the monotony of life and to enrich the intellectual interest—so often mean and meager. As an active educational agency the museum should be in close and sympathetic touch with the public schools. Visits of teachers with groups of pupils should be encouraged. With people beyond school age, much may be done by lectures, classes and by scientific organizations. Attention should be directed not merely to the strictly scientific features of natural history, but also to the broader aspects and deeper meanings of nature, whence come sympathy, insight and refreshment of spirit.

As a setting for this work, the museum building should be simple in construction and planned with a view to economical management. Elaborate decoration or architectural effects are not desirable. Money can be expended to better advantage in other ways. Problems of lighting, construction and arrangement of cases, and the distribution of material call for careful attention. The general color effect and the background for objects are important elements in adding to the attractiveness of the collections. Cleanliness, neatness and abundant light are the cardinal virtues of the museum.

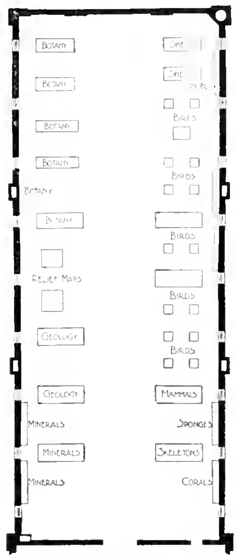
An illustration of the possibilities open to a small museum is afforded by the recent development of the Museum of Natural History, in Springfield, Massachusetts. This institution had its beginning in 1859, and was in a measure the result of interest aroused by a meeting of the Association for the Advancement of Science, held in Springfield that year. At the outset, the museum was placed under the control and care of the City Library Association, and this relation has been maintained ever since to the advantage of both institutions. For many years but little was done apart from the gathering of specimens, and dependence was in the main placed on contributions from local collectors. The result was a large amount of material, not always correctly classified, and decidedly miscellaneous in character. Better quarters were provided in 1871 in the new library building, and the museum was reorganized and brought into close relationship with the scientific department of the high school. In 1895, a commodious and suitable hall was provided for the collections in the Art Museum. The material was carefully classified and arranged for the first time on a systematic basis. With the new facilities, there came a notable increase in activity; public interest was enlisted and large gifts of specimens and money were made. Class-work, lectures and scientific societies were begun. In a few years the museum had outgrown its

new quarters, and in 1898 it was provided with an attractive and commodious building for its own use.

The general plan and details of the building are made in accordance with the recognized needs of the institution, so that without any sacrifice of appearance, the care and supervision of the collections are reduced to lowest terms. The dimensions are: width, fifty feet; length, one hundred and fifty feet. In the front portion, which contains two stories, there are on the ground floor a library and the curator's office, and up-stairs a small class room and the department of archeology and ethnology. Beyond these apartments, and approached by a wide entrance hall, is the main exhibition room, forty-six feet wide and



SCIENCE BUILDING · FLOOR PLANS



FLOOR PLAN SHOWING ARRANGEMENT OF MUSEUM OF NATURAL HISTORY

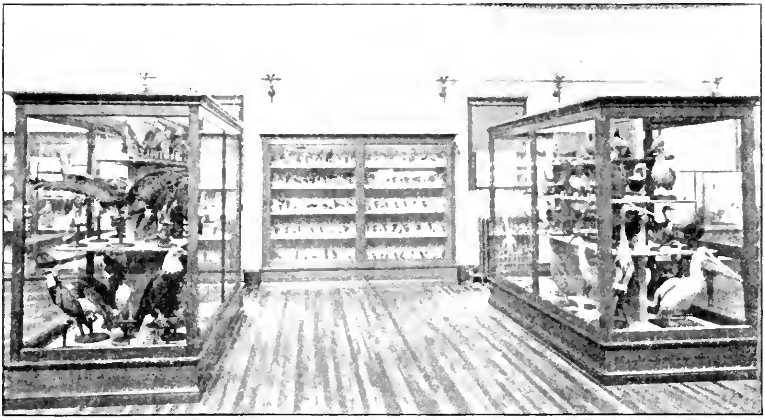
twenty-two feet high. All the collections are on one floor and are lighted from overhead, a method that has proved most successful. Side windows are used chiefly for ventilation. By an abundant supply of electric lamps in the form of ceiling disks and wall brackets, the room can be brilliantly lighted in the evening. A series of radiators is placed under the side windows, so that there is no loss of wall or floor space. The floor is of selected maple, finished with an oil varnish. A simple and systematic arrangement of the collections is made possible by the size and shape of this room. Especial care has been taken to make the basement suitable for the storage of duplicate material for class and laboratory work. The floor is of Portland cement. At least

six feet of the room is above the grade of the building, and there is generous window space so that the lighting is better than is found in many museum halls. In general the building is a modern French adaptation of Greek and Roman styles and is constructed of Pompeiian brick with trimmings of Indiana limestone and terra-cotta. The chief ornamental feature is the portico with massive limestone foundations and its four great columns of polished granite. The building is somewhat removed from the street so that the noise of traffic is escaped. It is situated near the center of the city and in close proximity to Library, Art Museum and High School. The opportunity thus afforded of cooperation between these institutions has been utilized with excellent results.

An important element in the success of the museum is the excellence of the cases. They have been designed so as to secure the largest possible glass surface and adequate protection against dust. The frames are of quartered oak and are fitted with the highest grade of plate-glass. In adjusting the shelves, the display of specimens to the best advantage has been constantly kept in mind, and the cases have been modified according to the kind of material exhibited. A buff color has proved most satisfactory for a background. On the main floor there are now ten standing cases, each ten feet long, four feet wide and seven feet high. This height seems most convenient for the utilization of all shelf space. There are thirteen wall cases of somewhat smaller dimensions than the standing floor cases. Four table cases are used for material in botany and two desk cases for shells and birds' eggs. For animal groups there are in all seventeen cases, making a total of forty cases in the main museum, to which must be added eight wall cases and two desk cases for the material in archeology, and historical relics. In the desk cases, only the upper part is used for display of specimens, and the space below is fitted with drawers for the preservation of duplicate and study collections.

The arrangement of the museum has been based on the principle of a simple and systematic grouping that should give an attractive appearance; where such a course seemed desirable, liberty has been taken to depart from a strictly formal classification. On the left side of the main hall are collections in mineralogy, lithology and geology. One alcove contains the Samuel Cotton Booth collection of local minerals, and a wall case is devoted to specimens of unusual rarity or beauty. This material is supplemented by relief maps, as, the Colorado cañon, the Volcanic District of the Auvergne in central France, the United States with a representation of the glacial ice-sheet, and southern New England. Photographs, wall maps and models complete the geological exhibit. In the basement there is a large amount of material for laboratory work and for illustration of local formations. In time, the latter

will be placed in the main room and will constitute a fine presentation of the geology of Springfield and vicinity. Botany shares with geology the left side of the main hall. Under this division there is an extensive



THE MUSEUM OF NATURAL HISTORY. SOME OF THE CASES.

herbarium of local flora, specimens of woods of North America and the Bahamas, that show tangential, cross and radial sections, and illustrations of the cocoanut palm, Indian corn and vegetable fibers.

THE MUSEUM OF NATURAL HISTORY. VIEW FROM NEAR ENTRANCE

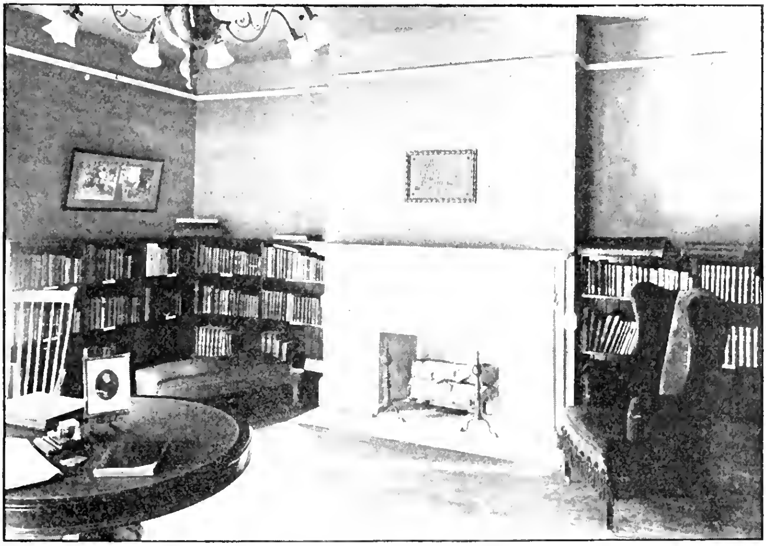
Zoology, on the east side of the room, is represented by a very complete collection of local birds in the form of individual specimens and as groups in reproductions of the natural environment. There are fifteen of these groups, and they comprise the following species: song

sparrow, American robin, spotted sandpiper, Indian bunting, Baltimore oriole, red-winged blackbird, wood-thrush, oven-bird, rose-breasted grosbeak, scarlet tanager, vireo, king-bird, bobolink and quail. The last group to be installed is an excellent representation of the prairie-hen. These realistic imitations of birds and insects amid their environment of foliage, blossoms and grasses constitute a feature of the museum that appeals with peculiar interest to children. Under the head of zoology there are good collections of corals and shells; the latter with over two thousand specimens, representing two hundred and twenty-nine genera and one hundred and seven species. Entomology is represented by twenty cases of butterflies with a total of two hundred and thirty-five specimens, twenty-two cases of moths with three hundred and twenty-three specimens and five boxes containing orthoptera, gall wasps and micro-lepidoptera with ninety-seven specimens, and three cases showing the life history of moths. There is also a study collection of one hundred and seventy-two noctuid moths. Some notable additions have been made to the department of mammals in the past few years. Mention should be made of an albinistic northern Virginia deer, an unusually rare specimen. A muskrat group, measuring five feet by seven feet, six inches, and showing the home of the animal in winter and summer with the environment carefully reproduced has been recently installed.

Last summer the museum received two remarkable gifts, a group of elk and one of buffalo. Each requires a case sixteen by sixteen feet on the floor and twelve feet high. The elk family of three members is placed among barberry bushes, quaking ash trees, moss-covered logs and stumps, in a veritable imitation of a woodland scene. Remarkable skill has been shown in the mounting of the animals, the arrangement of material and the modeling of the plant life, the leaves and blossoms. A bit of open prairie, with characteristic vegetation, constitutes the setting for the group of bison and is as effective in all respects as that of the elk. These additions are a means of attracting visitors and thus promote the popularity of the museum. As specimens of native animals, whose numbers are rapidly decreasing, their value will increase with years. The mounted mammals are supplemented by a series of skeletons of typical vertebrates. Attention is now being given to the better development of the department of mammals, especially in the direction of the local fauna.

In the upper story of the front portion of the museum building, there is on exhibition material in archeology, historical curios and ethnology. The Indian relics are of wide range in kind and geographical distribution, and the Connecticut Valley in which Springfield is situated is well represented. Out of a total of over three thousand specimens, seven hundred and sixty-six are from this valley and four

hundred and forty-nine from Massachusetts and Connecticut beyond the limits of the valley. Professor Albertus T. Dakin, of the Peabody Museum, at Cambridge, has made this report on a part of the collection: "It constitutes a very interesting and valuable addition to any museum, but is of more than ordinary value to this community because of the fact, that with few exceptions, the entire collection of stone implements was gathered in the near vicinity of Springfield and all the specimens of stone art have been found within the confines of the Connecticut Valley. It is, moreover, one of the largest, if not the largest collection of distinctly local material that has been brought together and exhibited under one roof." Two important gifts, the Booth loan collection, and fifteen hundred carefully selected specimens given by



CATHARINE L. HOWARD MEMORIAL LIBRARY OF SCIENCE. FIREPLACE, TABLET AND BOOKCASES.

Dr. Philip Kilroy make up the largest part of the Indian relic collection. In the arrangement of the material a scheme has been followed that shows the geographical distribution, while at the same time the various implements have been grouped to illustrate the development of primitive art and industry and the uses of the different articles. Photographs, maps and descriptive labels furnish additional information in regard to the life of the Indian. Every facility is offered in the use of the collection for study and research. Under the auspices of the museum, a beginning has been made in the examination of old camp sites, quarries and fireholes in the vicinity, and some interesting results have been obtained already, with the promise of richer discoveries in the near future. A few cases devoted to historical relics and curios complete the material on exhibition in the museum.

The Catharine L. Howard Memorial Library, which is placed in a room at the left of the entrance hall, is a valuable aid in the work of the institution and is an efficient factor in encouraging study and research. It contains about six hundred standard reference volumes in the different branches of natural history. Geology is represented by the latest editions of Geikie, Dana, Lyell, Sedgwick, Le Conte, Lapparent and Credner, monographs on local geology, Dana's 'System of Mineralogy,' Williams' 'Crystallography' and Zittel's 'Paleontology.' Students of botany will find among other books the 'Natural History of Plants,' by Kerner and Oliver; Britton, Gray and Sargent. Zoologists will find Scudder on butterflies, 'Das Tierreich,' 'Cambridge Royal Natural History,' Woodward on the mollusca and authorities of like standing in all lines of the study of animal forms. The library is furnished after the fashion of a private room and provided with facilities for quiet reading. All books are accessible to readers, but none may be taken away.

By reason of the simplicity of the museum building, the excellence of the cases and careful installation of the collections at the outset, the work of administration has been conducted at very slight expense and with a small staff of attendants, and much time has been given to the active educational work of the museum. Constant effort is made to enlist volunteer assistants in the various lines of activity and to awaken popular interest in the different phases of natural history. The open hours are from two to six o'clock during the summer season and from one to five o'clock in the winter, but the collections are practically accessible at any hour of the day. Various devices are employed to make the room attractive and cheerful. The main hall is decorated by tropical plants, as palm, sago and century plants, in themselves an interesting study.

An especial effort has been made to bring the museum into close and helpful relations with the public schools. Out of duplicate material, collections illustrative of geology, mineralogy and lithology have been prepared and placed in various schools in the city and in near-by towns, where they have done good service in the branches of nature study undertaken by the teachers. Within the past year arrangements have been made with the school authorities whereby pupils are brought to the museum in charge of instructors and in groups of such size that the greatest advantage may be gained. It is an interesting sight to see eager children gathered around a case or about a table of specimens, intent on the explanations and busy with pencil and note-book. While the scheme of museum visitation has not yet been thoroughly systematized, there is a steady growth in attendance, interest and results. During the year 1901–02, sixty-six classes, accompanied by teachers, visited the collections, with a total attendance of eight hundred and sixty-three.

Apart from the class visits, teachers are making a practice of sending individual pupils to look up specimens and seek information at first hand. This plan has been followed more particularly in bird and plant study. Another means of rousing interest is through competition for prizes for the best collections or reports. Last year the supervisor of nature study offered a prize for the best collection in mineralogy, and the twenty-seven sets of specimens entered were exhibited in the museum and attracted much attention. This fall prizes were awarded for the best work done in collecting and studying beetles by any pupil below high school grade. In connection with this contest, two talks were given on 'Beetles and how to collect them,' and two excursions were conducted under the auspices of the museum. Ten children presented collections numbering in all 1,806 beetles. The prize winner had collected 202 species and 28 food plants. A number of rare specimens were among those presented, and the results showed that the young people had spent much time on the work with genuine interest and careful thought. There are many profitable lines on which such contests may be conducted.

Pupils from the high school are encouraged and guided to use the museum in connection with the study of zoology, botany, mineralogy and physiography. Teachers in the high school draw freely on the resources of the collection for specimens and are allowed under simple conditions to take out specimens for use in recitations and lectures.

Cooperation between schools and museums has been worked out in detail in many places in England, notably in Liverpool, Leeds and Manchester, and with excellent results. The director of the Liverpool Museum, Henry O. Forbes, in a special circular dated July, 1902, reaches the following conclusion: 'That these efforts to interest children in nature study are producing good results is strikingly demonstrated by the way in which school children avail themselves of holidays to voluntarily visit our museum—the fact of a school holiday being of late always unmistakably indicated by the invasion of the museum by school children who evince a growing interest in the exhibits.'

Each year definite class-work is conducted in the Springfield Museum. During the past winter, twelve exercises on the chemical and physical properties of minerals with simple tests for determination were given by the assistant curator. A volunteer class in plant study was formed in the early spring and has continued to hold weekly meetings, with the exception of the two months of summer. Another means of arousing public interest has been found in the informal evening openings. During the season of 1901–02, six talks were given at these openings on such topics as 'Vegetable Fibers,' 'Industrial Insects,' 'The History of a Lake,' and on 'Plants,' 'Buds' and 'Galls.' Special

invitations were sent to people who do not generally visit the collection, and the results in attendance and interest were most gratifying. The daily attendance on the museum makes a total for the year of about 30,000, and this number steadily increases.

Several scientific societies find their home in the museum building. The botanical society has for many years held weekly meetings during the spring, summer and fall. The herbarium is in charge of the curator. The geological club uses the collections and reference books and as one result of its excursions specimens are added to the museum. By means of this club young people are given an interest in local geology and with this object in view the organization is making a careful study of the formations in and about Springfield, with excursions to interesting localities. The zoological club maintains a series of valuable meetings and has been fortunate in securing able lecturers from the many educational institutions in the near neighborhood. Meetings of all these societies are open to the public. There are now under consideration plans for the organization of holiday and vacation rambles whereby groups of children may be brought into sympathetic and intelligent relations with their surroundings and individually interested in particular phases of nature study. For mature minds regular lecture courses conducted on university extension methods are a possibility of the near future.

Another means of enlisting popular interest and promoting serious study has been found in special exhibits made from time to time. In the late winter, spring and early summer, the migrant birds that appear each month are displayed on the table and the specimens denoted by their scientific and popular names. Reliable reference books are near at hand. On the bulletin board a calendar is kept of the appearance of each species and a comparison made with the dates of previous years. These observations are printed in the annual report of the museum. The results for last spring, 1902, pointed to an unusually early arrival of many migrants. A similar arrangement is followed on the table devoted to botany, where one finds buds and blossoms as they appear. Early in the year the winter condition of certain plants is shown, and the progress in the development of leaf, buds and blossoms as they advance. On February 15, the chickweed, *Stellaria lucidea,* was found in bloom, and on the twenty-eighth, the skunk-cabbage, *Symplocarpus fœtidus.* The hood of the latter was cut so as to expose the spadix with its many flowers. Then followed in order, hepatica, bloodroot, marsh marigold, trailing arbutus and other spring flowers and tree blossoms. By the opening of June the exhibition had reached such an extent that another table was added. Twelve species of orchids were shown. One rare and beautiful flower, the *Pentstemon grandiflorus,* not supposed to exist east of the Mississippi, was found on the outskirts of the city.

In all about four hundred separate plants were shown to the close of July. The exhibit was discontinued in July, but in September was opened again with various compositæ, as asters and golden rod, together with gentian and witch hazel, and as winter came on with cryptogams, as toadstools, lichens and mosses. Pupils in the high school have cooperated in the work by preparing lists to show the dates of the appearance of different blossoms. Corrected lists are published in the annual report and in time these will add materially to our knowledge of the flora of the region. There is also printed in the report a classified list of flowering plants and ferns growing on the museum grounds. Plans are under way for an exhaustive study and complete herbarium of the flora of Forest Park.

In planning lectures and exhibits, the museum officials are on the alert to take advantage of any special interest in the minds of people. Some years ago when there was much discussion of the value of mushrooms and the importance of care in collecting them, there were placed on special tables with careful descriptions many of the most common and important species. The exhibit of birds and plants appeal to an innate interest, easily aroused and maintained. Evidences are many that these various activities and influences of the museum are in a quiet but effective way developing in the community a spirit of sympathy, power of observation and a delight in the wonderful treasures of nature.

A city of the wealth and population of Springfield is certainly fortunate in the possession of a museum of natural history of such excellence and of collections so extensive and of such value for exhibition purposes and for study. These things have been made possible by the fine public spirit that characterizes the community. The City Library Association, including the Library, Art Museum and Museum of Natural History, constitutes a rallying point for the various interests in matters literary, artistic and scientific. Much of the efficiency and influence of the association is the result of the untiring and unselfish devotion and labors of the late Rev. Dr. William Rice, librarian from 1861 to 1897. Such is the confidence of the people in the work of the institution that the city makes each year a generous grant of money to meet the running expenses of the three departments of literature, art and science. In land, buildings, books and collections the total value of the property is nearly, if not over, $600,000, most of which has been the gift of public-spirited citizens. On account of the simplicity of the museum building and the excellent work done on the cases, and care taken in the installation of the collections, this department of the association is conducted at a minimum expense. The total annual appropriation to cover salaries, repairs, cleaning and lighting is $1,200, and this amount is rarely exceeded. Yet the museum is em-

phatically an active institution, and has never lacked zealous and enthusiastic workers. By an inevitable law of growth, as the museum is active and progressive, it constantly demands more room and greater facilities. Already in the short space of eight years it has twice outgrown its quarters. While the present building is commodious, the needs of the future were kept in mind in both construction and site, so that successive additions can be made until the building forms a quadrangle. When this extension is completed the main divisions of natural history, geology, botany and zoology will each have a floor space equal in extent to that of the present structure. With such a building Springfield's needs for museum facilities will be amply satisfied and the range of work and influence broadened.

And the field for the museum of natural history when conducted with enterprise and wisdom is one that well repays all effort and labor. Much of the best instruction in the public schools, training in observing and reflecting on the facts of nature is well adapted to assist the museum, while the latter institution, rightly used, widens the outlook. A growth in familiarity with the region surrounding the city makes possible profitable holiday rambles and vacation outings for the study of local natural history. There may be developed a love and appreciation of the delights that nature has in store for her students. Such pursuits are antidotes for the cares and perplexities that burden too many lives, so that a more healthful tone will pervade the social life of the community; nature opens her treasures to rich and poor alike, and the fullest indulgence in these joys carries no sorrow with it. In the larger centers well-equipped museums may well serve as training schools and points for the distribution of materials and examples of the best methods of administration. Their influence could be brought to bear on the smaller towns. Such a system with a very moderate expenditure of money would do much to relieve the barrenness and monotony which too often characterize the intellectual and social life of the country town.

COLLEGE ENTRANCE EXAMINATIONS.

BY ABRAHAM FLEXNER,

LOUISVILLE, KY.

OF all the influences molding secondary education in the United States at the present time, among the most powerful are the college entrance examinations. To the schoolmaster they seem to embody in tangible form the object of his efforts; to the student they form a barrier that must be cleared, interposed as they are between him and that fascinating interplay of social, athletic and perhaps scholarly activities, called college life. It becomes, therefore, a question of immediate and pressing importance—what conception of education do these examinations tend, perhaps unconsciously, to establish?

In scholarship tests they yield a result that is treated as absolute; no consideration suggested by the development or individual history of the student is suffered to modify or illumine their verdict. The ignorance and the impartiality of the examining authority compel the rejection of all factors except the visible question and its answer. But in the secondary school period neither knowledge nor the rehandling of knowledge can, save at the peril of growth, be regarded as the sole or main educational end. The accumulation of facts, the mastery of tools must be subsidiary to the inward ordering of the pupil. While this work of organization must proceed side by side with, indeed largely by means of, the acquisition of knowledge, the two processes do not form an equation. In a word, definite quantitative, even definite qualitative performances in certain limited areas of knowledge can not be immediately translated into mental and moral terms. A limited acquaintance with certain predetermined selections from Greek, Latin and English literatures may or may not connote the concentration, energy and power of resistance which genuine training should confer; there is no necessary or inevitable connection between them. What we want is a method for measuring energy, growth, organization. An examination, therefore, which seeks not only to value past effort, but to decide the very possibility of future opportunity simply upon the basis of a uniform scholarship test, emphasizes scholarship, such as it is, at the expense of organization. It tends inevitably to produce a special, narrow fitness for meeting a particular form of test at the cost of spiritual spontaneity, and, in consequence, the verdict of the schools is usually upset by the verdict of subsequent experience.

I say the examinations emphasize scholarship; but do they? In each subject they aim to cover a clearly defined requirement. As a means of eliminating caprice this is excellent and effective; but too literal insistence upon the most admirably defined requirement is fatal to the scholarly, the vital quality. The larger interests, the vaguer gropings, that in youth mark the mind with developmental possibilities are distinctly discredited in favor of the nimble, lightly cumbered, Athenian knack of the trained 'examinee.' Knack is the quality produced and honored by the examination test, hastily and externally administered. Ability to guess the answer through the question, mechanical celerity in applying the formula to the problem—be the problem historic, linguistic or mathematical—cleverness in seizing and elaborating an idea frequently implied in the interrogatory, a special trick of remembering odds and ends, phrases or comments—in a word, breezy facility—such is the ideal equipment for the college entrance test. The candidate will surely be overweighted by genuine love of his subject, witnessed by large, though necessarily vague and immature acquaintance with it. His chance of passing will be better if he has not wandered beyond the 'assigned' and has that at his finger tips. For the foreign examiner is not seeking evidence of power, of energy liberated and directed to intelligent purpose. With this—the real business of the real teacher—he has no concern. He stands fast by the letter; he must have the special nuggets of knowledge. The effort to satisfy such tests is thus not only fatal to a lofty conception of the teacher's office—it is equally fatal to genuine scholarship, poor a substitute as is mere learning for that spontaneity of consciousness at which culture and training should aim. Taste, capacity, originality are thus heavily discounted by staking the issue on something that taste, capacity and originality soon learn to regard with disgust. Hence, too often, those who have most successfully lent themselves to the 'mill treatment' prescribed, are those whom the fuller tests of scholarship, professional training and practical life reject as lacking scope, pliability and interest.

I am sure that our collegiate 'lords and masters,' overwhelmingly interested as they are in specialties rather than in boys, do not realize the deadening and restrictive effect of this mechanical emphasis of the letter. What shall it profit a student to develop a real love of Shakespeare at the expense of a thorough and intimate knowledge of the notes to Macbeth? What shall it profit him to extend his acquaintance with Milton beyond the designated poems and books, if in the process he forget why the 'Vision of the guarded Mount' looked 'toward Nomancos and Bayona's hold'? Of course, no student retains such lore beyond the day appointed for its display. The melancholy truth is that it is retained so long only by means of mechanical reitera-

tion, much more likely to injure than to encourage good taste, and patiently submitted to only by those who never read literature as literature at all.

If too precise insistence upon arbitrarily assigned tasks is thus fatal to both vital teaching and scholarly interest, rigid limitation to brief and uniform examination periods is equally fatal to thought. We profess the desire to train students to coherent, logical ratiocination, to supplant the capricious mental spurt with the steady stream of thought. But the written examination, as now carried on, places at a marked disadvantage the intellect that has learned to work with deliberate discrimination. At a given moment the examination athlete darts his eye swiftly through the question paper, searching for some familiar sign, and at its sight dashes off the answer that is waiting for that particular provocation. No adequate time for reflection, no allowance for individual or accidental variations! The mind that refuses to operate in this reckless fashion is not 'ready'! The student who has read widely rather than crammed recently, is not 'ready'! Meanwhile, the sprinter equipped for just these spurts, without real power of thought, observation or concentration, satisfied with superficial compliance with requirement—or less—moves nimbly from topic to topic, touches lightly here and there, and with a 'make-believe' that the stranger can not penetrate, presents as the hammer falls a smooth and more or less finished result.

Such conditions are so far from promoting readiness of thought that they simply negative all thinking. They substitute a lightning reflex for the deliberate working of the higher thought centers. I can not believe that top-speed has, even in practical life, the importance here attributed to it by implication; and if it be urged that only 'average' speed is desired, I answer that the supposed process of averaging is an absurdity. The slower intellects refuse to be averaged with the swifter. Each has the sacred right of individuality, and no educational effort can be considered sound that suffers one to waste part of its natural superiority, while it endeavors to compel the other to be something that it is not and, except in a limited way, can never become. Doubtless speed will increase with the formation of a thorough and logical mental habit. But the seriousness of the occasion, the liability to temporary fluctuation, which the examiner can not distinguish from permanent characteristic, and the importance of ascertaining things of infinitely greater significance than the boy's ability to work under pressure for a time, combine to render the present method both unfair and unwise.

I have referred to the 'Jack-be-nimble, Jack-be-quick,' type of examination athlete; let me not overlook his heavy-laden brother—the hoplite to whom the thing is as earnest and important as it pre-

tends to be. For him there is no youth; his life is a hard and unremitting cram, and he comes out of the ordeal, bereft of spirit, originality, spontaneity, too often of health besides. In exchange for these he carries a premature load of ill-assimilated pedantry, of neither disciplinary nor inspirational value, and destined soon to slip from his all-too-rigid grasp. Often enough, the college years witness a violent recoil—mental and physical. But for the time being he is the idol of the examination boards. He is ready to solve in all seriousness their linguistic and historic puzzles. He will promptly state facts to illustrate any random quotation; he has at his tongue's end a sentence each to describe 'the successive governments in France between 1789 and 1870'; he can mark all the long vowels in 'Cæsar,' and tell you what goddess gave any oracle that you can cull from the 'Metamorphoses'!

I regret that lack of space makes it impossible for me to submit complete specimens of recent examination papers in support of these criticisms; but the system as a whole is condemned by the absolute exclusion of all evidence beyond the answers submitted. I insist that it is fit for little more than to measure superficial knowledge; that, if it pretends to measure thought at all, it does so under conditions that practically forbid thought; that necessarily its influence on previous education tends to develop the external, mechanical and insincerely imitative at the sacrifice of the internal and spontaneous. The erection of so artificial a standard must lead to neglect of the proper educational business of youth, viz., the organization of each individual from within in harmony with his environment. Whatever connection may be charitably supposed to exist between such organization and the pursuits prescribed for college entrance, it can not be seriously maintained that the correspondence is so definite that it can be described in uniform quantitative terms, applicable to all students in all circumstances. Therefore, howsoever the questions be prepared and appraised, they can not alone be made the means of determining the issue without shifting the pedagogical emphasis from within to without.

In support of my contention that in its present administration the examination system is needlessly absurd, I have before me a very impressive mass of evidence. Here, for instance, is an examination in Roman history covering two printed pages, in which, under eight subdivisions, of which the candidate must select four, forty-one queries are submitted. 'Time allowed, thirty minutes'! Thirty minutes within which the youth is expected to comprehend the way the paper is put, read the questions in order to exercise the privilege of selection and commit to writing the answers to about twenty questions. Some of them are, it is true, mere matters of memory; but in this space of time, the candidate who stops to recollect is lost. Hence, nothing but

the sort of cram that disappears the day after the examination and risks the loss of all pleasure in history will provide instantaneous knowledge of such facts as 'The attitude of the Achæan league toward Perseus of Macedon; punishment inflicted by Rome for this; Polybius, the historian, as connected with this punishment,' etc. All this depends on the merest mechanical memory, but there is more to come. In the same thirty minutes, he is to display quick-action historic insight; for, as an original effort, he must 'tell the story of Appius Claudius as his political enemies would tell it, then as his political friends would tell it.' Now if the answer to this is merely a repetition of a previous attempt it is worse than worthless; if devised at the moment, assuming that the candidate has what he can not have—sufficient information at his command to warrant an honest answer—it must necessarily be superficial. The companion paper, in Greek history, requires the student in an equally brief half hour, after a varied memory performance, to 'argue that the Athenians were or were not wise in their final rejection of Alcibiades in 407,' and to tell 'what was the opinion of the comic poet Aristophanes in 405 about the wisdom of recalling him.' One can hardly go far wrong in recognizing the same keen educational intelligence in two previous papers, one calling mainly for the history of Capua, the other for the history of the Messenian wars. The display of such learned and irrelevant trifles is taken to indicate a proper knowledge of Greek and Roman history; and a teacher who is really trying to train boys must employ the history-tool so as to satisfy such tests! In truth this attempted draft on the historical imagination is but a transparent imposition, deceiving, not the children, who know the hollowness of the 'make-believe,' but the learned scholars who gravely require boys and girls after a study of the outlines of ancient history to 'compare Plato and Aristotle,' and in the same two hours, select and answer eleven other questions out of a paper containing forty, many of the single questions demanding from five to ten distinct answers.

The English papers present equally pernicious illustrations. In these days of the 'new' education, prominent educators congratulate us on the 'system' that has unified the entrance requirements in English! A board of experts selects in two groups some dozen or two everything everywhere. Now English A, so-called, consisting of things so appropriate to the universal youthful mind as Tennyson's classic gems, a knowledge of which is required of all candidates for 'Princess' and Lowell's 'Sir Launfal,' is to be touched lightly as a mere basis for composition; the examination uses the material thence derived to test the candidate's powers of expression. A process better calculated to torture the teacher and to divorce expression from experience in the pupil could hardly be devised. For the way in which the

selections must be used can be guessed from the fact that one paper before me requires the pupil to write in an hour and a quarter three original essays, 'correct in paragraph and sentence structure and general arrangement,' on subjects selected from twelve, of which the following are samples: 'What are the essential characteristics of the life described by Addison and Goldsmith as contrasted with the life in Ivanhoe'? or 'Compare the Ancient Mariner and the Vision of Sir Launfal with regard to the representation of a moral idea in each'? In one and a quarter hours a boy is to read and choose three out of twelve such problems, get his ideas into shape and set them down 'correct,' without the chance to reconsider, readjust, rewrite or recopy, which the most practised writer demands, and which every good teacher tries to get the pupil to require of himself!

English B is worse. The specimens consisting of 'Lycidas,' Burke's speech, Macaulay's 'Milton,' etc., must be dissected and 'crammed' in minute detail. One question before me requires the student to enumerate Burke's 'six causes'; another, after quoting five lines from the body of the speech, gravely asks what part of the oration follows immediately after; while still another requires, on the basis of Macaulay's two essays, a comparison between 'the political element in the life of Milton with the same element in the life of Addison'!

It is useless to go further into details; but I must not omit to call attention to the close connection between the examination papers in Latin and Greek and the fraud that is generally practised in their study. It is well understood among boys that to pass in these subjects one must have at ready command the assigned portions of the classics—one must be able to pick up the thread of narrative or argument, wherever the caprice of the examiner may choose to cut into it. The most effective and expeditious way to prepare is through the persistent use of 'interlinears' and 'trots.' A smattering of syntax, a fair knowledge of the forms, such as class room drill alone may be relied on to give, and a glib translation, such as daily surreptitious use of the 'trot' will infallibly ensure—these may be safely counted on to satisfy the present form of examination. What successful preparation for such tests costs the candidate in honesty, love and capacity for work, interest in the subject itself, one need not pause to calculate. It is only another illustration of the way an external and 'impartial' examination makes shipwreck of sound educational practice. The pupil detaches a fragment of his power, devotes it to devious uses, and 'passes'—the rest of his nature remains an unweeded and untilled garden.

I contend, therefore, that however the examinations be modified, the system that relies upon them solely is fundamentally unsound. For the closer the apparent articulation thus secured between secondary school and college, the more certain becomes the internal educational

hiatus. The larger the examination specter looms before student and teacher, the more decisive the tendency to neglect individual discipline and development, in order to perfect in their stead an organization calculated to meet the exigencies of a critical moment. Preparation for college entrance examinations, rather than preparation for college or preparation for life, insensibly becomes the educational goal. For clearly, when the whole future is staked on this single throw, the temptation to be effectively ready for it is irresistible. I say advisedly—the whole future; since by insistence on an academic degree as a prerequisite to the pursuit of law or medicine on the most highly favored terms, the professional schools aid in the production of the artificial crisis. Under these conditions, the field for pure educational effort in the secondary period threatens, despite the enrichment of the curriculum, to become steadily narrower. The initial and determining factor in the planning of a student's course of work is neither his endowment nor his opportunity, but the caprice that carries him to one institution rather than to another. This choice once made, it becomes increasingly difficult to persuade him to cooperate with his teacher in the endeavor to sound fully and genuinely his personal power. His absorbing interest lies in the statement of the college requirements; and so marked has this factor become that prominent schools do not hesitate to announce the particular colleges by whose requirements their curricula are regulated, as if any uniform requirements could possibly outline an educational procedure strictly applicable in even a single case.

Doubtless the secondary teacher will be roundly criticized by his collegiate superiors, just when he has, through the suppression of the student's individuality, succeeded in perfecting the preparatory machinery warranted to turn out the qualities and accomplishments demanded. For amidst collegiate conditions that begin by conceding to the student the possession of an individuality, which his previous training has, under collegiate compulsion, absolutely denied, it becomes at once manifest that preparation for college entrance examinations is not preparation for college. Indeed, for a college life, offering at the outstart liberal election in the whole field of knowledge and experience, what adequate training can be supposed to reside in the mechanical and uniform drill demanded by the entrance requirements? The articulation that seemed from superficial inspection so neat and complete turns out a delusion; the educational *sine quâ non* leads nowhere. In bygone days it may have fitted immediately into the prescribed freshman course. But no such justification now remains. Everywhere the developmental idea of power has driven out the superstitious faith that attached magic virtue to certain symbols—everywhere except in the peculiar domain where the nimble mastery of a few formulæ

is still thought to indicate a definite degree of mental growth and moral strength!

The situation, therefore, calls at once for examination reform, but it calls also for far more: we must harmonize under a sufficiently large ideal the various phases of developmental education. The elementary school, the secondary school, the college, have not yet been viewed and organized as essentially a single educational institution. Pending and in aid of their reorganization on this basis, I urge the colleges to emphasize the vital, not the mechanical, side of preparatory teaching; to establish fixedly no machinery that may impede the creation of a system subtly adapted to the individual. Our sore need now is of an intellect that shall conceive as a single whole the progression from childhood to maturity; that shall embody this progression in a connected series of educational institutions, from which every false, every mechanical, every pedantic test and motive shall have disappeared. Throughout, the system must be dominated by the effort to organize the child in effective harmony with his environment—it must aim at nothing else; it must be satisfied with nothing less.

A NEW SOURCE OF HEAT: RADIUM.

BY HENRY CARRINGTON BOLTON, PH.D.

AT a meeting of the French Academy of Sciences held in March MM. Curie and Laborde announced a newly discovered property of that extraordinary substance radium—its salts emit heat continuously and to a measurable extent. Readers of the POPULAR SCIENCE MONTHLY may remember that in the number for July, 1900, we sketched the history of the discovery of this new body by M. and Mme. Curie in 1898, and we gave some account of its marvellous physical and chemical properties so far as known at that date; its power of giving out light perpetually without any exciting cause, its emission of rays that penetrate solids like the X-ray, its faculty of acting on sensitized plates, and of causing air to conduct electricity. Now a fifth property must be added, that of the emission of heat.

During the few months that have elapsed since the publication of the above summary, physicists and chemists on both sides of the Atlantic have been actively experimenting with the interesting body, in no wise discouraged by its excessive rarity and by the great difficulty of obtaining it unmixed with the mineral substances by which it is always accompanied in nature. Tons of minerals have been submitted to laborious processes in the chemical laboratory to obtain a few grammes of the precious material; and at the end of the task the conscientious scientist can only claim that the product is such and such a salt containing a small, unknown percentage of radium.

To enumerate the peculiar activities of radium with any degree of completeness would occupy more pages of the magazine than could well be spared; for details we must refer to the purely technical journals, but some points arrest the attention of every one.

Becquerel, the French physicist whose name is attached to the rays emitted by uranium, observed the powerful physiological action of radium when in a comparatively pure state; a few grammes enclosed in a bottle carried in his waistcoat pocket burned holes into the flesh in six hours, producing superficial sores that took several weeks to heal. Some experimenters have remarked that their fingers are made sore by handling its salts. Aschkinass and Caspari have exposed cultures of *Micrococcus prodigiosus* to the influence of its rays and ascertained that they were fatal to the bacteria.

The character of the rays given out by radium has been the subject of special research; MM. Curie and Danne observed that solid

bodies submitted to the rays issuing from radium in a confined space, became active themselves in an analogous manner. On removing the bodies from this influence the power thus excited passes off in accordance with a given law independent of the nature of the bodies. In this connection experiments were made with bodies of diverse constitution, such as aluminium, copper, lead, bismuth, platinum, silver, glass, alum, paraffine, celluloid and caoutchouc.

Professor Rutherford, of Montreal, has found that this induced activity is produced by an 'emanation' that behaves like a gas, but this gas has not been isolated, or tested chemically or physically. In this connection it is of interest to note that Dr. Giesel, of Germany, also mentions a peculiar, colorless gas, having radio-active properties obtained by the decomposition of radium bromide.

The nature and extraordinary energy of the rays emitted by this singular substance has attracted much attention; it has been shown that they are of different kinds, a part being identical with cathode rays and another part capable of being still further divided into very penetrating rays, and those easily absorbed. Their energy is estimated by Rutherford and McClung to be prodigious; they calculate that one gramme of radium would radiate in a year energy equivalent to 3000 gramme-calories, which is about one foot-pound per hour. The source of this energy is a mystery; the savants last named suggest that it is due to the breaking down of atoms into smaller particles which themselves constitute these radiations.

Since it is universally admitted that the radiations are material the problem arises, does radium lose weight in the course of time? This question has been answered differently by two authorities. Becquerel has calculated from experimental data that one square centimeter of radium-surface would lose 1.2 milligrammes of matter in one thousand million years. On the other hand, Heydweiller found that five grammes containing only a small percentage of pure radium lost about 0.02 of a milligramme per day, and he observed a total loss of one half milligramme in a time not stated. The excessively small quantities of material available for examination and its exceeding rarity (a very small sample is valued at twenty-five dollars) will account for such contradictory statements.

The discovery by Curie and Laborde that radium emits heat was the result of two experiments. By a thermo-electric method they ascertained that a specimen of barium chloride containing one sixth of its weight of radium chloride indicated a temperature 1.5° C. (2.7° Fah.) higher than a sample of pure barium chloride; the temperature was determined by comparing the heat emitted with that excited in a wire of known resistance by an electric current of known intensity. In the second experiment they employed a Bunsen calorimeter. The ex-

perimenters found that one gramme of active barium chloride emits about fourteen small calories per hour. The specimen contained only about one sixth its weight of radium chloride, but on testing 0.08 gramme of purer material they obtained identical results, from which it can be calculated that one gramme of radium would emit 100 small calories per hour, or one atom-gramme (225 grammes) would emit each hour 22,500 calories, an amount comparable with the heat disengaged by the combustion in oxygen of one atom-gramme of hydrogen.

The continuous emission of such a large quantity of heat can not be explained by any chemical action, and must be due to some modification of the atom itself; if so, such a change must be very slow. As a matter of fact, Demarçay observed no change in the spectrum of radium examined at intervals of five months.

An English writer, commenting on the figures given by M. Curie, says that a radium salt in a pure state would melt more than its own weight of ice every hour; and half a pound of radium salt would evolve in one hour an amount of heat equal to that produced by burning one third of a cubic foot of hydrogen gas. And the extraordinary part of this is that the evolution of heat goes on without combustion, without chemical change of any kind, without alteration of its molecular structure, and continuously, leaving the salt at the end of months of activity just as potent as in the beginning. Yet this state of things must have a cause, for it must not be imagined that perpetual motion has been at last attained.

Persons who are not practically familiar with the work carried on in the laboratories of physics and chemistry are in danger of drawing unwarrantable conclusions from the statements made by imaginative reporters in the daily press, and of concluding that radium will eventually replace gas for illuminating purposes as well as anthracite for heating. Such persons do not realize the great scarcity of the raw material yielding this substance, nor the exceedingly minute quantities used in the experiments which have furnished these astounding results. A tea spoon would probably hold all the pure radium as yet prepared, and its price would amount to thousands of dollars.

And what may be expected from future researches? Do the other rare bodies, polonium, actinium and thorium, that behave in many respects like radium, also share its most recently discovered power of emitting heat? Will not scientists be compelled to revise some of the theories of physics that they regard at present as cardinal? And what are the conditions in the earth beneath our feet, when inert matter manifests energy to such an amazing extent without a known cause? The future opened to students and to philosophers is fraught with mysteries, the solution of which will be eagerly awaited by the rest of the world.

THE DECREASE IN THE SIZE OF AMERICAN FAMILIES.

By Professor EDWARD L. THORNDIKE,

TEACHERS COLLEGE, COLUMBIA UNIVERSITY, NEW YORK.

THE vital statistics of three other eastern colleges show the failure of Harvard graduates to produce their share of the present generation to be but a single example of a widespread condition. They further prove that the common discussions of the theoretical and practical questions which this failure suggests are superficial and misleading. In reality its explanation leads us directly to the fundamental problem of evolution. The facts are best seen in tabular form.

Size of Families of American College Graduates.*

The first number in each column gives the average number of children; the number in parenthesis gives the number of cases on which the average is based.

	Middlebury.	Wesleyan.†	New York Univ.‡	Harvard.
1803–1809	5.6 (64)			
1810–1819	4.8 (161)			
1820–1829	4.1 (163)			
1830–1839	3.9 (189)	4.5 (110)	(35–44) 4.0 (110)	
1840–1849	3.4 (83)	3.3 (220)	(45–54) 3.2 (83)	
1850–1859	2.9 (90)	3.2 (227)	2.9 (90)	
1860–1869	2.8 (114)	2.6 (250)	2.5 (66)	
1870–1874	2.3 (50)			
1875–1879	1.8§ (32)			1.99 (1872 inclusive) (634)
Total	946	807	349	634. In all 2,736

* These figures come in the case of Middlebury and New York University from the alumni catalogues, which give the number of children living and dead, from the answers to questions collected by Professor Nicholson in the case of Wesleyan University (both living and dead children are included), and from President Eliot's report, in which case only living children were counted. There are doubtless inaccuracies in the records, but the tendency of these would be to make our figures relatively too small for the *earlier* decades, and consequently truer records would only emphasize the decrease in productivity upon which all the arguments of this discussion will be based.

In the case of the Middlebury and New York University records, I have used only those families where the husband had been married at least ten years before he died. In the case of the Wesleyan records all married graduates have been included as the data required to make a selection on the basis of length of married life were lacking. I have to thank Professor F. W. Nicholson, Secretary of Wesleyan University, for the use of his records and Mrs. E. B. Brown for the report of the New York University graduates.

† The Wesleyan averages include cases from 41 *through* 50, etc.

‡ The New York University averages include cases from 35–44, 45–54, etc.

§ This average would be slightly raised by children to be born after th time of record.

These figures are from a sufficient number of cases to be substantially reliable. For instance, there is not one chance in a thousand that the Harvard average is 10 per cent. too low. The existence and approximate amount of the decrease in the size of family is thus certain. Its substantial identity in Middlebury, a country college in Vermont with a local attendance, in New York University, a city college, and in Wesleyan University, a strongly sectarian college with an attendance drawn from the northeastern states, makes it probable that it has prevailed throughout the college population of the north Atlantic states. It must depend upon some fundamental cause.

City life and advanced age at marriage are out of question. The former cause would work to a far greater extent upon New York University or Harvard graduates than upon Middlebury graduates, all of whom come from and most of whom go back to life in small towns. Yet in the statistics there is little difference. An increase in the age at marriage can not have been the cause for the simple reason that such increase, as I have elsewhere shown, amounts only to a very few months. An increase in the age at marriage of the wives of our group of men would be a more efficient cause. I know of no available statistics to decide the question, but it would seem extremely unlikely that the age of wives should have increased much when the age of husbands has increased so little.

The most plausible explanation attributes the change to the custom of conscious restriction of offspring. Greater prudence, higher ideals of education for children, more interest in the health of women, interests of women in affairs outside the home, the increased knowledge of certain fields of physiology and medicine, a decline in the religious sense of the impiety of interference with things in general, the longing for freedom from household cares—any or all of these may be assigned as the motive for the restriction. The only other explanation which to the present writer seems adequate assigns the decreased productivity of college men to real physiological infertility of the social and perhaps of the racial group to which college men and their wives belong.

It is possible to do more than speculate about the relative shares of unwillingness and incapacity. The figures themselves tell a plain story to the student who examines them in the light of recent knowledge of the variability of physical traits.

If we tabulate the records by decades so as to show the percentages that families of 2, 3, 4, etc., children were of the total number of families, we can see just how the decrease in the averages has been brought about. Suppose for instance that we had in 1803–1814 and in 1865–1874 the following percentages:

Children	0	1	2	3	4	5	6	7	8	9	10	11	12
1803–1814	0	0	2	4	8	10	16	20	16	10	8	4	2
1865–1874	10	15	19	8	4	5	8	10	8	5	4	2	1

It would be clear that the change was due to the substitution of families of 0, 1, 2 and to a slight extent of 3, for fifty per cent. of the families over 3, that all these groups of larger families had given up the same proportion to swell the groups of small families. This would point clearly toward restriction as a cause.

Suppose that the following were the facts:

Children	0	1	2	3	4	5	6	7	8	9	10	11	12
1803–1814	0	0	2	4	8	10	16	20	16	10	8	4	2
1865–1874	6	8	10	16	20	16	10	8	4	2	0	0	0

In this case it is clear that the change was due to the substitution throughout of families less in each case by three children. There is no cutting off equally from all the higher groups. Families of 4 and 5 for instance increase in number. There is no special increase of the 0, 1, 2 families. The movement has been simply a general decrease in size, a moving backward of the general tendency to produce. Such an appearance in the statistics would point toward decreased reproductive capacity.

In our second illustration there would probably be in connection with the lowered average tendency a reduction of the variability. That is the range or spread from the common occurrence (a four-children family) would be less, and our figures would be something like the following:

Children	0	1	2	3	4	5	6	7	8
1865–1874	4	6	11	17	24	17	11	6	4

Generalizing the argument we may say:

In so far as conscious restriction is the cause of the lesser fertility of the late decades it will show itself by a disturbance of the form of distribution of the different-sized families.

1. Restriction as commonly considered would increase the 0, 1 and 2 and to some extent 3 children families at the expense of all larger families. For according to the common view there would be no influence of restriction in a family which had already five or six children.

2. Each group of large-sized families would then lose in proportion to the number of families in it, the psychological and social sources of the custom being in no way correlated with fertility.

3. The result will be the appearance in the statistics of late decades of two species of families, one showing the natural tendency and in every way comparable to the species shown in the first decades, the

other a species of restricted families with a range from 0 to 3 or 4 and a preponderance of 2's and 0's.

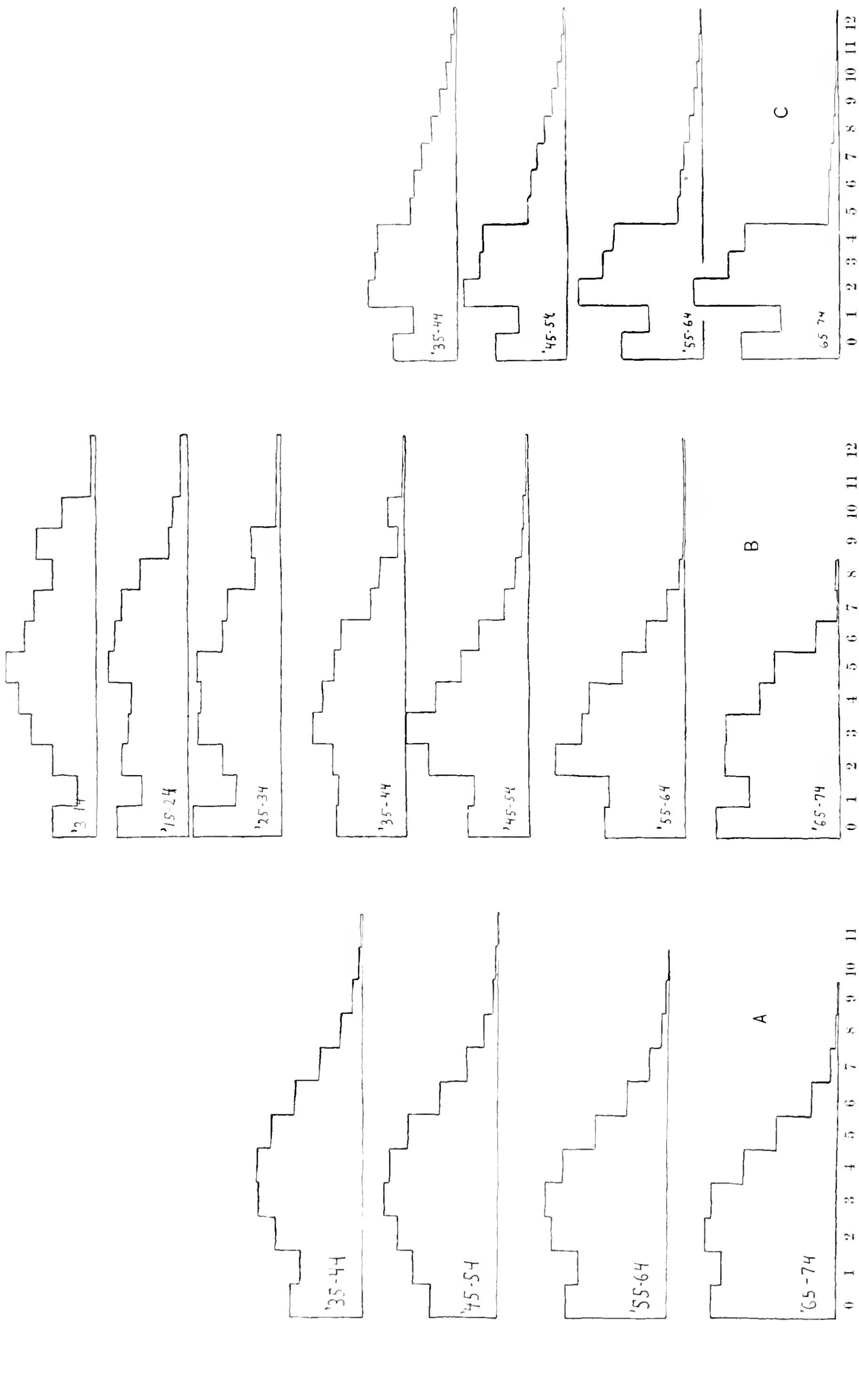
In so far as growing incapacity is the cause, it will show itself not by a disturbance of the form of the distribution of the different-sized families, but by a shifting of the whole distribution back toward a lower point, with probably a reduction of its variability or spread.

If now we turn to the actual facts we shall see that restriction of this type is utterly inadequate to explain them, while a growing incapacity would explain them very well.

The comparison of what has actually occurred with what would have occurred as a result first of growing restriction and second of decreased fertility may be more conveniently made by the use of graphic representations than by the numbers. There are thus presented: (A) the changes that would have occurred if the real fertility of this species of individuals had decreased to a bit less than one half what it was in 1803–1825, the variability being reduced in proportion to the square root of their average; (B) the actual changes in the size of families of college graduates from 1803–1874, and (C) the changes that would have occurred if the reduction in the average size of families had been due to an increase in the number of families in which the natural fertility had been restricted to from 0 to 4 children. In the last case I have calculated the result upon the hypotheses that 2 would be favored by forty per cent., 0 and 3 by twenty per cent. each, and 1 and 4 by ten per cent. each. But any other distribution of the restrictions would lead just as emphatically to the same general conclusions. Still more so would a restriction to families of from 0 to 3 children.

This conclusion is that the changes in distribution actually found decade by decade have far more likeness to those that would result from a decrease in fertility, than to those that would result from restriction. Indeed, the likenesses in the first instance are so close as to force upon us the conviction that the causes are identical. If one forgot the common opinions about the prevalence of restriction and looked directly at the facts he would say: The general fertility sinks from 5 to 2–3; the very large families become impossibilities, the range of possibility which was from 12 to —2 has changed to from 8 to —3 or —4; this species, whatever it is, is dying out. The facts are surely sufficient to rule out restriction of the type described, but before jumping to the conclusion that the obvious explanation of the statistics by a steady decrease in fertility is the true one we must seek other possible explanations of them.

Among such explanations that have been suggested to the writer none seems satisfactory. It might be thought that restriction was to 3, 4 and 5 in the early decades, to 2, 3 and 4 in 1835–55, and finally


A
'35-44
'45-54
'55-64
'65-74
B
'3 14
'15-24
'25-34
'35-44
'45-54
'55-64
'65-74
C
'35-44
'45-54
'55-64
'65-74
0 1 2 3 4 5 6 7 8 9 10 11 12

to 1, 2 and 3. But we can not then account for the great number of zeros in the early decades, nor for the way in which the reduction of the variability occurs. Again it might be thought that there has been a growing reluctance to have families over a certain size, a reluctance that becomes more and more intense in the case of large sizes. But it is impossible to find any scale for the increase of this reluctance such that by assigning more and more individuals to the reluctant class we can derive a series of distributions by decades at all like those actually found.

Of course if we postulate both a lowering with time of the size to which families are restricted and a sliding scale of reluctance that also varies with time we can account for the observed facts. Such a hypothesis is, however, suspicious because of its complexity and apparent artificiality. I do not deny that it may be true, but until we find some further support for it, we are bound so far as the observed facts go to prefer the *vera causa* which explains the observations with perfect simplicity, and to attribute the numerical degeneration of our group to a real decrease in fertility.

So far as our general mental prepossessions go, however, a real decrease in fertility seems at first sight a preposterous doctrine. One can well imagine the sneer of the physician whose experience emphasizes the frequency of restriction and the pitying smile of the biologist who discerns that a progressive decrease in fertility of a species is a flat contradiction of the doctrine of natural selection. 'Play on with your statistical hair-splitting,' they would say, 'Nothing that you find will disturb our beliefs. We know better.'

But I venture to assert that the experiences of metropolitan physicians will not serve to prophecy the social psychology of the species we have studied, that their opinions may here be as wide of the mark as the common belief that unwillingness is the main cause of the failure of the women of the better classes to nurse their children. As to the contradiction of natural selection, I may suggest that the existence, amount and results of the elimination of types by their failure to produce their kind is after all a problem which only statistical inquiries can settle and that if the doctrine is to be used as an excuse for evading certain obvious facts in human history it is perhaps time that it should be questioned.

The issue is clear. The more fertile members of a race produce of course a larger measure of the next generation than do the less fertile. So also do their children, if fertility is inherited. There should then, according to present-day biology, be a quantitative evolution of fertility. Absolute sterility would needs be the first trait to be eliminated from a species. It should have disappeared from the human stock æons ago. And so long as there are variations in fertility and

a transmission of these variations the fertility of a race must keep up to the racial type and ought to increase. It makes no difference whether the type can change only by sudden extreme variations or by a gradual change of its center of gravity. Of whatever sort the effective variations are, the ones that must needs win in the case of fertility are variations on the plus side. But what we actually find is good evidence of a decrease.

Although such emphatic facts as those reported here have never previously been at hand, the question has been clearly seen. In 'A Statistical Study of Eminent Men' in the February number of this MONTHLY, Professor Cattell called attention to the apparent inadequacy of natural selection to account for the rise and fall of nations. A note in the April number referring to the Harvard statistics also suggests the dilemma of the doctrine. The question is there raised whether even if the failure to produce were due to a psychic epidemic of restriction, there should not be on current biological theory a natural selection for certain inheritable mental traits of those individuals who resisted the epidemic and consequently a maintenance of race productivity. Our returns give support to this claim since the three generations involved should give nature a fair amount of time. I shall not, however, make any use at this time of this argument.

The decision of the question is equally clear. In so far as the decrease in the size of families is due to a real decrease in fertility, we have an absolute disproof of racial progress by the perpetuation of the characteristics of those who survive and reproduce. It is a simple question of fact. A comparison of families of different epochs, all of which are known to be unrestricted, would give an indubitable answer, and the argument here must not be a flourish of vague generalities.

So far as present facts go the probability is against natural selection in the case of fertility in man. The contrary hypothesis, that a stock like an individual has a birth, growth, senescence and death; that, apart from the onslaughts of rivals or the privations of a hard environment or the suicide of universal debauchery, races die a natural death of old age, lends itself very well to the interpretation of human history and perhaps to the history of animal forms as well. It leaves the causation of this race life and death as a mystery. But a mystery is less objectionable than a contradiction.

HELEN KELLER: A PSYCHOLOGICAL AUTOBIOGRAPHY.*

By Professor JOSEPH JASTROW,

UNIVERSITY OF WISCONSIN.

THE interest in the story of Helen Keller is many sided. To the public at large the personal interest naturally dominates; for the story of the development, in spite of seemingly impassable curtailments of experience, of a bright child into an intellectual young woman forms an intensely interesting and deeply human document. As an experiment in education the account is most valuable; at one point it reinforces principles already advocated upon other varieties of evidence; at another it opposes a narrow overvaluation of method or theory; at many others it illuminates the profound significance of the essentials, and throws into relief the secondary values of the ways and means of a real education. For the psychologist the narrative is no less important. It contributes notably to the interpretation of the rôle of sensation in the building up of intellectual acquisitions; it furnishes pertinent illustrations of the delicate interlacing of the strands of experience—throughout conditioned by natural endowment—in the composite pattern of the mental texture.

Born June 27, 1880, at Tuscumbia, Alabama, of good ancestry, the child was deprived by a serious illness that befell her at the age of eighteen months, of both sight and hearing. Taste and smell remained normal, and her physical health continued to be excellent. At the time of her illness, the child had already spoken a few words, one of which—'wah-wah' for 'water'—may have been retained through the illness and the sightless and silent years that followed. Miss Keller believes that something remains to her of the glimpses of the world during her first months of life. 'If we have once seen,' she cites, 'the day is ours, and what the day has shown.' One must not underestimate the value of such continuity of experience as is possible even at so tender an age; yet it may be said that practically her mental life began anew amid her altered and restricted environment.

The five years before the 'light of the world' was brought to her are suggestive of the spontaneous ingenuity of the child under such

* 'The Story of My Life,' by Helen Keller with her letters (1887–1901), and letters of her teacher Anne Mansfield Sullivan, supplemented by John Albert Macy. New York, Doubleday, Page & Co., 1903, pp. 441, 8vo. The illustrations we owe to the courtesy of the Volta Bureau, Washington, D. C., and of Messrs. Doubleday Page & Co.

unusual conditions. Signs were developed by mutual suggestion between her and her family. "A shake of the head meant 'No' and a nod, 'Yes,' a pull meant 'Come' and a push, 'Go.' Was it bread that I wanted? Then I would imitate the acts of cutting the slices and buttering them. If I wanted my mother to make ice-cream for dinner I made the sign for working the freezer and shivered, indicating cold." "I understood a good deal of what was going on about me. At five I learned to fold and put away the clean clothes when they were brought in from the laundry, and I distinguished my own from the rest. I knew by the way my mother and aunt dressed when they were going out, and I invariably begged to go with them." She played with the children about her and thus records how she did it. "I could not tell Martha Washington when I wanted to go egg-hunting, but I would double my hands and put them on the ground, which meant something round in the grass, and Martha always understood. When we were fortunate enough to find a nest I never allowed her to carry the eggs home, making her understand by emphatic signs that she might fall and break them." Writing at the age of ten, she says: "When I was a very little child I used to sit on my mother's lap all the time, because I was very timid, and did not like to be left by myself. And I would keep my little hand on her face all the while, because it amused me to feel her face and lips move when she talked with people. I did not know then what she was doing, for I was quite ignorant of all things. Then when I was older I learned to play with my nurse and the little negro children, and I noticed that they kept moving their lips, just like my mother, so I moved mine too." Here is another recollection of her childish play: "My aunt made me a big doll out of towels. It was the most comical, shapeless thing, this improvised doll, with no nose, mouth, ears or eyes—nothing that even the imagination of a child could convert into a face. Curiously enough, the absence of eyes struck me more than all the other defects put together. I pointed this out to everybody with provoking persistency, but no one seemed equal to the task of providing the doll with eyes. A bright idea, however, shot into my mind, and the problem was solved. . . . I found my aunt's cape which was trimmed with large beads. I pulled two beads off and indicated to her that I wanted her to sew them on my doll. She raised my hand to her eyes in a questioning way, and I nodded energetically." Obviously the little girl's mind was developing, though doubtless with far greater slowness and difficulty than would have been the case under more normal circumstances. Her moral training under the natural indulgence to one so afflicted suffered; and fits of passion and a lawless disregard of social amenities were a frequent occurrence.

It was through Charles Dickens's account of Laura Bridgman,

published in his 'American Notes,' that Mrs. Keller became acquainted with the possibilities of education for one in Helen's position; and on March 3, 1887, Miss Sullivan came to Tuscumbia from the Perkins Institution in Boston—where Laura Bridgman lived—to take charge of Helen Keller. The first approaches to a mutual understanding between pupil and teacher were naturally dependent upon the utilization of the primitive sign language to which we all resort, with a success proportionate to our ingenuity, when thrown among those whose language we do not understand. Of this meeting Miss Sullivan wrote at the time: "She felt my face and dress and my bag, which she took out of my hand and tried to open. It did not open easily, and she felt carefully to see if there was a key-hole. Finding that there was, she turned to me, making the sign of turning a key and pointing to the bag." Later they went upstairs together and there, says Miss Sullivan: "I opened the bag, and she went through it eagerly, probably to find something to eat. Friends had probably brought her candy in their bags, and she expected to find some in mine. I made her understand by pointing to a trunk in the hall and to myself and nodding my head that I had a trunk, and then made the sign which she had used for eating and nodded again. She understood in a flash and ran downstairs to tell her mother by means of emphatic signs that there was some candy in the trunk for her." Miss Sullivan records a further instance of the child's spontaneous signs. "She had signs for *small* and *large* long before I came to her. If she wanted a small object and was given a large one she would shake her head and take up a tiny bit of the skin of one hand between the thumb and finger of the other. If she wanted to indicate something large, she spread the fingers of both hands as wide as she could, and brought them together, as if to clasp a big ball."

These instances are suggestive of the considerable range of perceptions and activities that even a deaf-blind child can acquire without the use of words. The concentration point of Miss Sullivan's efforts was the revelation to the 'infant' mind of the existence and the potency of a word. The humble instruments thereof were a doll and a piece of cake. The doll was given to the child and the deaf-mute signs for 'd-o-l-l' made by Miss Sullivan in the child's hand. "She looked puzzled and felt my hand, and I repeated the letters. She imitated them very well and pointed to the doll. Then I took the doll from her, meaning to give it back to her when she had made the letters; but she thought I meant to take it from her, and in an instant she was in a temper and tried to seize the doll. I shook my head and tried to form the letters with her fingers; but she got more and more angry. . . . I let her go but refused to give up the doll. I went downstairs and got some cake (she is very fond of sweets). I

showed Helen the cake and spelled 'c-a-k-e' in her hand, holding the cake toward her. Of course she wanted it and tried to take it; but I spelled the word again and patted her hand. She made the letters rapidly, and I gave her the cake." Meaningless as this finger-play must have been to the seven-year-old child, it was hardly more so than

MISS HELEN KELLER (1893).

other of the arbitrary relations between causes and effects that a child readily accepts as part of the logic of reality. But the magic touch that was to supply 'the light that failed' was not far off. The really serious obstacle was the difficulty of sustaining human relations with this willful bit of humanity, and of enforcing discipline. After a few

trying struggles, victory rested with the teacher; and the taught, once initiated into the charm of the new occupation, was fascinated thereby. After about a fortnight of this constant forming of letters in the child's hand and pointing to objects thus designated—such as 'mug,' 'milk,' 'father,' 'mother,' 'walk,' 'sit,' 'water'—the notion that objects were designated by the signs was grasped; and a ceaseless quest for names of all the things with which she was familiar was begun. Miss Sullivan thus describes the moment of inspiration. "We went out to the pump-house, and I made Helen hold her mug under the spout while I pumped. As the cold water gushed forth filling the mug, I spelled 'w-a-t-e-r' in Helen's free hand. The word coming sc close upon the sensation of cold water rushing over her hand seemed to startle her. She dropped the mug and stood as one transfixed. A new light came into her face. She spelled 'water' several times. Then she dropped on the ground and asked for its name, and pointed to the pump and the trellis, and suddenly turning around, she asked for my name. I spelled 'teacher.' . . . All the way back to the house she was highly excited, and learned the name of every object she touched, so that in few hours she had added thirty new words to her vocabulary."

An illustrative instance of these early lessons in which moral teachings and material rewards are mingled with letters and simple occupations is the following: Helen had been rebellious in regard to the use of her napkin. Miss Sullivan arranged the table fittings but omitted the cake which was the reward for spelling a word correctly. "She noticed this at once and made the sign for it. I showed her the napkin and pinned it round her neck, then tore it off and threw it on the floor and shook my head. [This had been Helen's behavior.] I repeated this performance several times. I think she understood perfectly well; for she slapped her hand two or three times and shook her head. We began the lesson as usual. I gave her an object, and she spelled the name. (She knows twelve now). After spelling half the word she stopped suddenly, as if a thought had flashed into her mind, and felt for the napkin. She pinned it round her neck and made the sign for cake (it didn't occur to spell the word, you see)." With this as the 'premier pas qui coûte,' the further progress, though at first slow, was direct and cumulative. On March 31 Helen knew eighteen nouns and three verbs; the next day she added eight more. On May 22 her vocabulary was estimated at three hundred words; on June 19 at 400 words; at the end of August at 625 words; at the close of her first year of instruction at 900 words. 'Open' and 'shut' were learned by the manipulation of a door; as early as June 12, while holding some worsted for her teacher, she spelled to herself repeatedly 'wind fast, wind slow'; 'in' and 'on' were illustrated by putting Helen

in the wardrobe, or the doll *on* the table. Confusions occurred; 'mug' and 'milk' were associated in a common action, and only gradually was each given its own name. Sentences followed naturally and quickly. Then she was introduced to raised letters and learned the mystery of reading. Later the art of Cadmus was presented, and within less than four months from her first word-lesson she wrote a letter of thirty words, recording childishly but clearly a few simple facts.

Her desire for expression was marked from the outset. "I used to make noises," she recalls, "keeping one hand on my throat while the other felt the movements of my lips. I was pleased with anything that made a noise and liked to feel the cat purr and the dog bark. I also liked to keep my hand on a singer's throat, or on a piano when it was being played." In 1890 the girl of ten years, though conversing fluently by the manual alphabet with those who could read these flying symbols of speech, felt that she was cut off from direct intercourse with her fellow creatures. 'How do blind girls know what to say with their mouths?' she asked her teacher. By allowing Helen to place her hands upon the throat and lips of the speaker and then inducing her to place her own vocal organs as nearly as possible in the same position she learned to make the sounds. These, with infinite patience and years of close training, were made to be readily intelligible, though naturally far from the perfect articulation that the ear produces. Deaf children are constantly taught to speak in this way; the added difficulty in this case is that the eyes can not read the lips and visually imitate the positions in articulation. For the deaf-blind this task must be delegated to the less ready guidance of the tactile sensibilities. Such an individual learns to speak orally as do the deaf, to read by touch as do the blind. The permanent peculiarity of the double deprivation is for Helen Keller her best and normal mode of receiving words—by interpreting the finger-letters of the deaf as they are made in the palm of her hand. In this way she 'listens with her hands.'

The details of her education are now rendered accessible to all. The several stages from kindergarten occupations and spelling-games to courses in philosophy at Radcliffe College are graphically set forth. The range of her present capabilities is indeed remarkable; and the writing of the autobiography not the least of them. For the slow process of writing with a pencil—which is reduced to tactual guidance by writing on paper placed against a grooved cardboard back—she has substituted the typewriter, the space relations of the keys being as accurately fixed in her motor memory as they are in the visual memories of those that see. Neither of these forms of record can the blind themselves read. For their own use a system of pricked points—sim-

ple combinations of which form the letters—is adopted; such 'Braille' writing is done on a simple machine operated by a key-board. It is in this form that Miss Keller read and revised the chapters of her autobiography. When a stranger meets Miss Keller and wishes to communicate directly with her, she places her fingers against his lips

MISS HELEN KELLER AND MISS SULLIVAN (1898).

and throat, and thus reads the sounds as they emerge. This requires slow and distinct articulation on the part of the speaker, and considerable filling in by guess-work on Miss Keller's part. The letters formed in her hand is distinctly the superior method; yet pronunciation can be taught by the lip-reading method only. In this way she has learned

to speak French, German, Italian, to say nothing of her school experience of Latin and Greek. Her range of language, expression and comprehension is thus no mean one, confined though it be to the avenues of touch and motion.

It is interesting to trace the evidence of this 'touch-mindedness' in the imagery of her well-formed and expressive style. Her recollections of the days of her childhood, as well as her more mature experiences contain many of them. In reading them it should be recalled that they include sensations of temperature and—very important to the deaf—the impressions of jar or vibration, which present a rich variety of distinctive qualities.

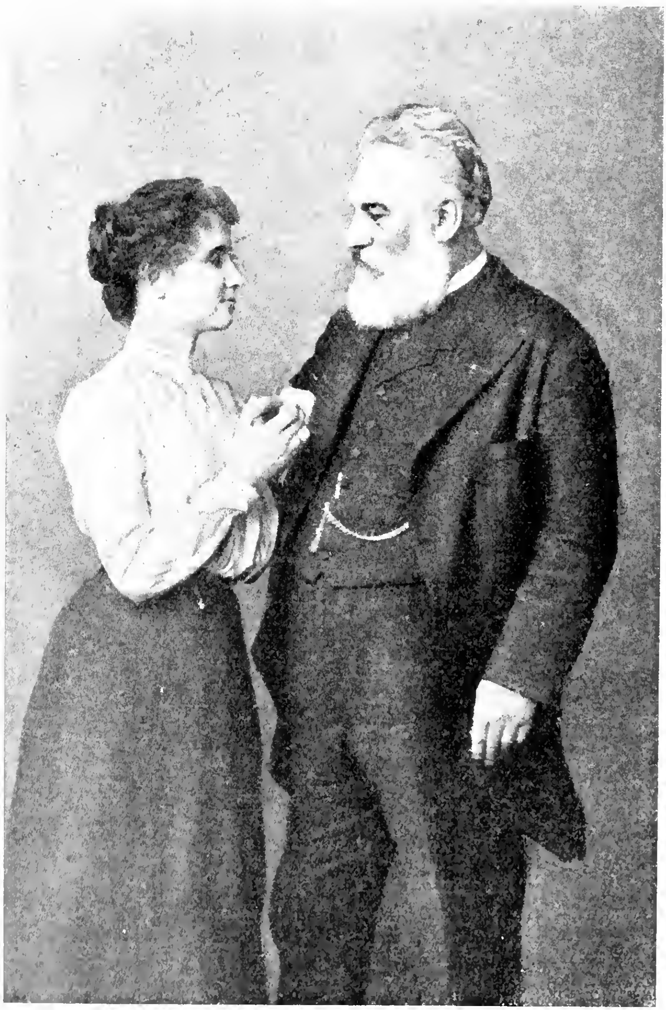
"Oh, the delight with which I gathered up the fruit in my pinafore, pressed my face against the smooth cheeks of the apples, still warm from the sun, and skipped back to the house!" Of the Plymouth rock: "I could touch it, and perhaps that made the coming of the Pilgrims and their toil and great deeds seem more real to me. I have often held in my hand a little model of the Plymouth rock which a kind gentleman gave me at Pilgrim Hall, and I have fingered its curves, the split in the center and the embossed figures '1620,' and turned over in my mind all that I knew about the wonderful story of the Pilgrims." "The rumble and roar of the city smite the nerves of my face, and I feel the ceaseless tramp of an unseen multitude, and the dissonant tumult frets my spirit. The grinding of heavy wagons on hard pavements and the monotonous clangour of machinery are all the more torturing to the nerves if one's attention is not diverted by the panorama that is always present in the noisy streets to people who can see." With Mr. Jefferson as he personated for her Bob Acres writing the challenge: "I followed all his movements with my hands, and caught the drollery of his blunders and gestures in a way that would have been impossible had it all been spelled to me. Then they rose to fight the duel, and I followed the swift thrusts and parries of the swords and the waverings of poor Bob as his courage oozed out at his finger ends. Then the great actor gave his coat a hitch and his mouth a twitch, and in an instant I was in the village of Falling Water and felt Schneider's shaggy head against my knee." "The hands of those I meet are dumbly eloquent to me. The touch of some hands is an impertinence. I have met people so empty of joy that when I clasp their frosty finger tips it seemed as if I were shaking hands with a northeast storm. Others there are whose hands have sunbeams in them, so that their grasp warms my heart. . . . A hearty handshake or a friendly letter gives me genuine pleasure." When an organ was played for her: "I stood in the middle of the church, where the vibrations from the great organ were strongest, and I felt the mighty waves of sound beat against me, as the great billows beat against

a little ship at sea.'' Of a test of Helen's hearing when she was eight years old, Miss Sullivan writes: "All present were astonished when she appeared to hear not only a whistle, but also an ordinary tone of voice. She would turn her head, smile and act as though she had heard what was said. I was then standing beside her, holding her hand. Thinking that she was receiving impressions from me, I put her hands upon the table and withdrew to the opposite side of the room. The aurists then tried their experiments with quite different results. Helen remained motionless through them all, not once showing the least sign that she realized what was going on." "A medallion of Homer hangs on the wall of my study, conveniently low, so that I can easily reach it and touch the beautiful, sad face with loving reverence. How well I know each line in that majestic brow—tracks of life and bitter evidences of struggle and sorrow; those sightless eyes seeking, even in the cold plaster, for the light and the blue skies of his beloved Hellas, but seeking in vain; the beautiful mouth, firm and true and tender. It is the face of a poet and of a man acquainted with sorrow." Her occupation during a lecture at college is thus described: "The lectures are spelled into my hand as rapidly as possible, and much of the individuality of the lecturer is lost to me in the effort to keep in the race. The words rush through my hand like hounds in pursuit of a hare which they often miss. But in this respect, I do not think I am much worse off than the girls who take notes. If the mind is occupied with the mechanical process of hearing and putting words on paper at pell-mell speed, I should not think one could pay much attention to the subject under consideration or the manner in which it is presented. I can not make notes during the lecture because my hands are busy listening."

The position of the sense of smell in the commonwealth of sensation is for *Homo sapiens* not a very lofty one. Its exercise is limited, and even when efficient, it is tabooed by the dictates of good manners. Yet it combines, even in those with a full quota of senses, with other forms of knowledge-getting, and frequently has a leading associative force. For the deaf-blind any 'window of the soul,' however narrow its aperture, is a welcome source of illumination; and it is easy to discover in the narrative of Helen Keller's experiences, references and allusions that clearly indicate the direct and associative value of olfactory impressions.

"We walked down to the well-house, attracted by the fragrance of the honeysuckle with which it was covered." "Suddenly a change passed over the tree [in which she was seated]. All the sun's warmth left the air. I knew the sky was black, because all the heat, which meant light to me, had died out of the atmosphere. A strange odor came up from the earth. I knew it was the odor that always precedes

a thunderstorm, and a nameless fear clutched my heart." "One beautiful spring morning when I was alone in the summer-house, reading, I became aware of a wonderful subtle fragrance in the air. . . . 'What is it?' I asked, and the next minute I recognized the odor of the mimosa blossoms." "We read and studied out of doors, preferring



Miss Helen Keller and Dr. A. Graham Bell (1902).

the sunlit woods to the house. All my early lessons have in them the breath of the woods—the fine resinous odor of pine needles, blended with the perfume of wild grapes." "It was delightful to lose ourselves in the green hollows of the tangled wood in the late afternoon, and to smell the cool delicious odors that came up from the earth at

the close of day." In a camping party: "At dawn I was awakened by the smell of coffee, the rattling of guns, and the heavy footsteps of the men as they strode about, promising themselves the greatest luck of the season." "The air was balmy with a tang of the sea in it." "I felt the low soughing of the wind through the cornstalks, the silky rustling of the long leaves, and the indignant snort of my pony as we caught him in the pasture and put the bit in his mouth—ah me! how well I remember the spicy, clovery smell of his breath!" In describing her visit to Dr. Holmes, she writes: "There was an odor of print and leather in the room which told me that it was full of books." Miss Sullivan relates that when she took Helen, as a child, to church, she smelled the wine, when the communion service began 'and sniffed so loud that every one in the church could hear.' When rowing on the lake at Wrentham in the summer time, she recognizes the direction in which the nearest shore lies by the odors from the shrubbery on the shore. She may even recognize the part of the lake by the specific recognition of some blossoms that grow at some known spot.

While it thus becomes sufficiently evident that the deprivation of the two most intellectual of the senses leaves an indelible impress upon the habits and manners of the mind, yet the community of the mental economy as well as of the materials which it employs and of the language in which it finds expression, is by far the more notable factor in the comparison. Whether we travel by train or by diligence or on foot, the destination is the same when reached. The one mode of conveyance is swift, the other cumbersome, and the third arduous; each requires an equipment with which the others may dispense. For all the view from the mountain top is much the same, however wearisome the climb. What Miss Keller records of her resolution to go to college is true in large measure of her whole career. "I knew that there were obstacles in the way; but I was eager to overcome them. I had taken to heart the words of the wise Roman who said, 'To be banished from Rome is but to live outside of Rome.' Debarred from the great highways of knowledge, I was compelled to make the journey across country by unfrequented roads—that was all; and I knew that in college there were many bypaths where I could touch hands with girls who were thinking, loving and struggling like me."

And yet the 'journey across country by unfrequented roads' is not quite the same as the bustling traffic along the highway. It is because of this difference that we admire the perseverance and testify to the inherent endowment of one who has reached the goal in spite of disabilities profound. It is difficult, in limited compass, to set forth the dominant traits of Miss Keller's personality; it is the less necessary as the reading of the autobiography will convey a far more convincing

realization of what she is and thinks and does than any sketch could suggest. During the first three years of her instruction she more than made up for the deficiencies to which her deprivations had sentenced her; and one can not but be impressed, upon reading the letters written before her tenth year, with the linguistic facility and the breadth of imagination of the child. Then, under more systematic guidance, she learned to speak and laid the elementary foundation for the arts and crafts of life. The desire to prepare for college was one of her early ambitions and became formulated into a definite plan of campaign at about her sixteenth year. The range of studies required for entrance she duly mastered, showing very unequal gifts for the various branches, and especial strength in her knowledge of languages, literature and history. It is no small tribute to her talents that in spite of no natural bent for mathematics and with the special difficulty that geometrical relations must present to a 'tactual' mind, she acquitted herself creditably in this study. At the moment of the publication of her book she is closing her junior year at Radcliffe College. She has evidently gained much from her academic associations; and not the least of the confidence that her friends express in her future is based upon the mental growth that has been characteristic of these collegiate days. A reading of the selections from her themes in the course in English and from her more recent letters, indicate a certainty of touch in the handling of language as well as a noteworthy power to sustain an argument, that certainly meets the customary standard that one would be willing to apply to student writings. Such unusual achievements would have been impossible without an unusual endowment; alertness and vigor of mind, a remarkable memory, a keen observation and fertility of imagination, a pronounced taste for the literary side of life, good spirits and a ready sense of humor, comprehensiveness and saneness of interests, a sympathetic and enthusiastic temperament, a love of nature as well as of books—these are the traits that impress one as most potent in shaping her life and her aspirations.

It is quite true that the same could be said for many another individual whose biography remains unwritten, and whose achievements are not entered upon the tablets of a hall of fame. The absurd exaggerations and distorted accounts of Miss Keller's career, that have gained currency, are much to be deplored. We feel so overwhelmingly our own dependence upon what we see and upon what we hear, that we naturally drop into hyperbole and exhaust our adjectives in expressing our appreciation of one who has done so much without these invaluable handmaids of the mind. Yet the truer interest lies in the training that has been imparted to the normally less skilful servants, and in the mastery that has thus been gained. It is this aspect of Helen

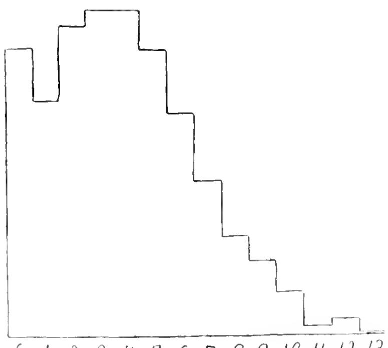
Keller's story that gives it the significance of a psychological biography.*

* The presentation of Miss Keller's story as a biography has left no place for the tribute that every account thereof should pay, and pay liberally, to the skill and devotion of Miss Sullivan. It is difficult to say what would have become of Helen Keller under less wise and less able guidance. The deep appreciation of the problem to which she has devoted her life is shown in Miss Sullivan's contemporaneous letters. These letters form a most valuable portion of the volume. Free from theory or narrow devotion to any system, Miss Sullivan's pedagogic tact detected the essence of the situation, and her insight quickly discovered the ways and means for further progress. The educational success, as well as our knowledge of how it was obtained, is immeasurably indebted to the discerning insight of Miss Sullivan.

DISCUSSION AND CORRESPONDENCE.

PROFESSOR PEARSON ON THE DISTRIBUTION OF FERTILITY.

In a note concerning the question of the birth rate in the April number of the Monthly, you quote Professor Karl Pearson's distributions of fertility and also refer to his measurements of the resemblance between mother and daughter in fertility. The skewness of the distribution of fertility in the case of the Quaker families probably represents no real condition, but is due to a statistical procedure, namely, to the combination in one distribution of groups of individuals of a number of different generations. As I show in an article in this number of the Monthly, the distribution of natural fertility in



any one decade is approximately normal, there being no pronounced skewness save that due in late decades to the undistributed zeros. But if I combine all my results from Middlebury College, using thus families of men born from 1780 to 1850, I get a curve, as shown in the diagram, like Professor Pearson's in its pronounced positive skewness. If we suppose, as I am sure we must, that in Professor Pearson's Quaker families, the families are of larger and larger size as we go back in time and that also the number of families examined is fewer and fewer as we go back in time, we must conclude that even if the distribution were perfectly normal at any one period the total score would give just such skewness as he found. The abnormality of his distribution is thus a sign of the statistical mixture of species, not of any essential physiological characteristic. Of the Copenhagen records I can not speak assuredly as I do not know how the individuals were distributed in time. The occurrence in Professor Pearson's records of families of 13–22, higher that is than any that I have found in over 2,000 families of the last century, would seem to show that the beginning of the decadence of the American stock dates back beyond the nineteenth century.

It is possible too that the resemblance in fertility between mother and daughter which Professor Pearson has measured, and naturally enough attributed to heredity, may be really due to the necessary nearness in time of a mother and her daughter. If, for instance, in five generations fertility dropped steadily from 10 to 2, and we calculated a coefficient of filial correlation for a group of mother-daughter pairs distributed throughout the five generations, we should have a result showing marked mother-daughter resemblance, although heredity, as measured by the comparison of measures taken relatively to the average fertility at the time the individual lived, might amount to *nil*.

Edward L. Thorndike.
Teachers College,
New York.

SCIENTIFIC LITERATURE.

PHYSIOLOGICAL CHEMISTRY.

SINCE the publication of the brief review in the August number of the MONTHLY, the literature of this subject has continued to receive important additions, which indicate the increasing influence of the chemical aspects of biological study. The appreciation of this fact has given rise to the appearance of the *Biochemisches Centralblatt*,* under the editorial supervision of P. Ehrlich, E. Fischer, A. Kossel, O. Liebreich, F. Müller, B. Proskauer, E. Salkowski and N. Zuntz. These well-known names alone suffice to assure a future for the new journal, which is to report at brief intervals abstracts of chemical or biochemical investigations having a bearing on the biological sciences and medicine in particular. It is hoped in this way to enable the chemist, the physician and the general biologist to obtain a brief survey of the entire domain of activity along related chemical lines of work. The few numbers of the *Centralblatt* already at hand contain, in addition, cursory reviews of the literature upon restricted topics, *e. g.*, the proteids, alimentary processes, etc., written by competent scientists.

A more critical résumé is aimed at in the 'Ergebnisse der Physiologie,' † the first volume of which has recently appeared under the joint editorship of Professor Leon Asher, of Berne, and Dr. Karl Spiro, of Strasburg. With the collaboration of a large number of many well-known physiologists, it is proposed to publish yearly two volumes, one of which is to be devoted to biochemistry, the other to biophysics and psychophysics. The entire field of physiology will thus be reviewed from time to time in the form of essays, more exhaustive, critical and suggestive than any mere compilation of abstracts could be. If one may judge by the character of the contributions to the first volume, it seems inevitable that the 'Ergebnisse' will become an important work of reference; and it will serve, even better than most text-books, to keep the physiologist in touch with current progress in the study of the problems of biology.

Maly's 'Jahresbericht über die Fortschritte der Thierchemie' completes its thirty-first year under the editorship of Professor Andreasch and Dr. Spiro, the latter taking the place of the late Professor v. Nencki. Dr. H. C. Jackson, of New York, has been added to the list of contributors.

Dr. O. v. Fürth's 'Vergleichende chemische Physiologie der niederen Thiere * is one of the most valuable of the new books. The interest which the study of the lower forms has aroused lately has for the most part been confined to the more purely physical and morphological features of animal life. The chemical data accumulated during many years and scattered through various journals and monographs have now been collected by v. Fürth into a series of chapters useful for reference and helpful in suggesting opportunities for research.

* Gebrüder Bornträger, Berlin, 1903.

† J. F. Bergmann, Wiesbaden, 1902.

* Gustav Fischer, Jena, 1903.

THE PROGRESS OF SCIENCE.

WILLIAM HARKNESS.

In the death of Professor William Harkness, U. S. N., America loses one of the group of scientific men who have given this country high rank in its contributions to astronomy. While Harkness may not have made brilliant discoveries, he accomplished a large amount of painstaking work, and had an important share in the expeditions of the U. S. Naval Observatory and in arranging its equipment. He was born in Scotland in 1838, his father being a clergyman. He was educated at Lafayette College and Rochester University and studied medicine in New York City, being for a time surgeon during the civil war. He was appointed aid in the U. S. Naval Observatory in 1862, and his connection with this institution

William Harkness.

continued for thirty-seven years until his retirement with the rank of rear-admiral in 1899. Harkness served on the monitor *Monadnock* in its cruise through the Straits of Magellan, making exhaustive observations on the behavior of compasses under the influence of iron armor and also terrestrial magnetic observations. This work was published by the Smithsonian Institution in 1871. He observed the total solar eclipse of 1869 at Des Moines and of 1870 in Sicily. Soon thereafter he devoted himself to the arrangements for the transits of Venus in 1874 and in 1882. The former transit he observed in Tasmania, later spending some years in reducing the observations, in the course of which he invented the spherometer caliper. He observed the transit of Mercury in Texas in 1878 and the total solar eclipse in Wyoming in the same year, and devoted much time to editing and preparing the reports. Professor Harkness then carried out an important work in reducing the observations of the zones of stars observed by Gilliss in Chili, and later prepared his work on the solar parallax and its related constants. From the publication of that work in 1891 to his retirement he was principally occupied with the new building of the observatory, in devising and mounting its instruments and in establishing a system of routine observations. Professor Harkness on his retirement expected to take only a few months' rest, and then to continue his scientific work at Washington, but he suffered from nervous prostration, and for the four years until his death he was scarcely able to leave his house.

THE AMERICAN SOCIETY OF NATURALISTS.

BRIEF reference has already been made here to the meeting of the American Society of Naturalists held at Washington in convocation week in conjunction with the meeting of the American Association for the Advancement of Science and other scientific societies. The annual discussion before the society, the subject of which was 'How can endowments be used most effectively for scientific research,' has now been published. Professor Chamberlin, of the University of Chicago, who opened the discussion, spoke of the importance of endowing in connection with universities not only chairs and departments but also special schools and colleges of research. He said that instead of the colleges of the English universities, devoted mainly to personal education, the ideal university should be an association of colleges of research for the benefit of mankind as a whole. He also held that we need independent institutions of research and endowments for the coordination of research. Professor Welch, of the Johns Hopkins University, spoke with special reference to the Rockefeller Institute for Medical Research, describing what had been accomplished since its foundation two years ago, and foreshadowing the permanent institution, the establishment of which has since been announced. Professor Boas, of Columbia University, spoke with special reference to publications, arguing that academies and other institutions should unite their publications, so that series for each of the sciences might be established; the wasteful effects of competition and the exchange system of publication would then be supplanted by series that would became self-supporting. Professor Wheeler, of the University of Texas, criticized the present system of fellowships, and argued that fellows should be selected competent to carry on research, that they should not be regarded as recipients of alms, or required to waste their time on routine work, or do work beyond their power or in a place unsuited to it. Professor MacMillan, of the University of Minnesota, favored the multiplication of institutions and agencies for research,

and said that there is some danger lest too great cooperation might lead to subordination. Professor Münsterberg, of Harvard University, argued that the equipment for research in America is ample, the difficulty is in the lack of the right men. Americans are particularly well suited to research work, but the ablest students tend to follow law or business, where the rewards are greater. Endowments can accomplish the most by creating great premiums, as by establishing an 'over-university,' where the masters of research chosen by their peers would be brought together for work transcending the possibilities under existing conditions. The giving of subsidies to individual men of science and to existing institutions is a system of charity that will in the end weaken research.

The address of the president, Professor Cattell, of Columbia University, was on the natural history of men of science. He gave the following table, showing the number of American men of science and their distribution among the sciences by different agencies:

	Special Societies.	Fellows of Association.	Members of Academy.	University Professors.	Doctorates in Five Years.	Contributors to *Science*, 13 Vols.	Who's Who.	Biog. Dictionary (estimated).
Mathemat.	375	81	1	136	61	35	46	380
Physics	149	167	23	105	69	155	73	556
Chemistry	1933	174	12	143	137	73	166	656
Astronomy	125	40	12	41	16	48	51	212
Geology	256	121	13	55	32	161	174	436
Botany	169	120	7	57	53	94	70	416
Zoology	237	146	17	83	72	243	131	620
Physiology	96	10	2	53	18	22	25	156
Anatomy	136	10	0	56	1	13	18	116
Pathology	138	14	5	68	4	44	56	224
Anthropol.	60	60	3	4	5	56	37	92
Psychology	127	40	1	37	63	58	21	136
	3801	983	96	838	531	1002	868	4000

RACE SENESCENCE.

The article on 'The Decrease in the Size of American Families,' contributed by Professor Thorndike to the present number of the Monthly, is one of the first attempts to solve by scientific methods a scientific problem of the first magnitude. Incidental remarks by persons high in authority have led to numerous newspaper comments, serious and otherwise, on the failure of college graduates to reproduce themselves, and 'race suicide' has become a current term. The question of the decreasing birth rate has, however, for some years been a subject of discussion by French economists, and it has been recognized that the conditions in New England are similar. Indeed, nearly every country shows a decreasing birth rate, though only France and New England have a native population that is actually decreasing, destined, if present conditions continue, to be exterminated.

Attention has been attracted to the subject in France by economic conditions—the failure to maintain a population equal to that of Germany and Great Britain, the lack of young men for the army and the like—and economic and social causes have been assigned for the small families. The chief cause is said to be the method of dividing property among the children. The French peasant is a landowner, and if his property is to be maintained intact, he must have but one son, and can not afford to give the necessary *dot* to more than one daughter. Other causes are also alleged—the increase of luxury, high taxation, the crowding into cities, immorality, alcoholism, etc. It is nearly always assumed that the families are small because the parents wish to have them small, and the remedies proposed, such as exemption from taxation or the payment of bounties in the case of larger families, are based on this supposition. But facts are lacking. For example, if voluntary restraint due to the economic conditions usually alleged is the cause, and the French family wishes to have one son and not more, then when there is but a single child (as is the case in one fourth of all families), it would be more often a boy than a girl; the most common family of two would be a

daughter and a younger son and the most common family of three would be two daughters and a younger son. Apparently no such statistics have been collected or even proposed.

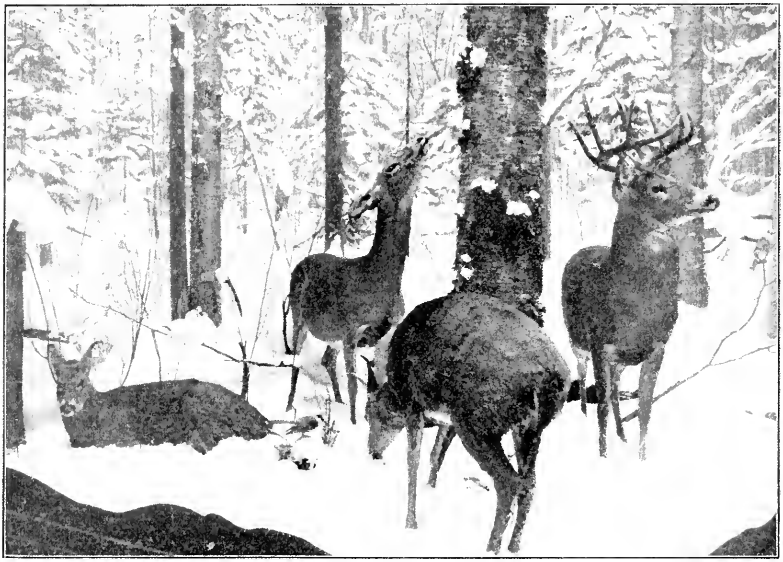
The alleged causes of the small families in France do not seem to obtain in New England. It is extremely improbable that all parents should voluntarily limit the size of families; the decreasing family must be in part due to physiological causes, which may be individual or racial. Individual causes may be late marriage, especially of women, school life and other unhygienic conditions, or an inhibition exerted by intellectual and other interests outside the family.

Racial sterility is certainly possible. It seems to conflict with the principle of natural selection, as fertility might be supposed to have a high selective value. Natural selection, however, can only select, it can not produce variations. If size of head is more variable than size of pelvis and is equally important for survival, the increasing difficulties of childbearing are not inexplicable on the theory of natural selection. If sterility increases, we must assume that the conditions of the environment have altered too rapidly for variation and natural selection to keep pace with them. Indeed the existing conditions may be due in part to our interference with natural selection. The decreasing death rate on which we pride ourselves may in part be responsible for the decreasing birth rate. When children who can not be born naturally or can not be nursed survive, we may be producing a sterile race. No statistics in regard to miscarriages are at hand, but there is good reason to believe that they increase as the number of children decreases. There is no positive proof of race senescence in man. On the contrary we know that the Italians and the French Canadians have large families, though there is as much reason for them to suffer from racial exhaustion as the inhabitants of France, and the Chinese seem to be in no danger of extermination. But we know that animals bred for special traits tend to become infertile, and selection for our civilization may have the same result. Physicists tell us that the earth may be uninhabitable in twenty million years; it may be uninhabited by man in twenty centuries.

THE FIELD COLUMBIAN MUSEUM.

THE Field Columbian Museum, of Chicago, has now been in existence for ten years and has during this period made important progress. It was organized in 1893 at the close of the exposition, from which it received its building and some of its collections. The following year the name 'Field Columbian Museum' was adopted, owing to the generous gifts made by Mr. Marshall Field. The building erected for temporary purposes is gradually falling to pieces, and it is said that Mr. Field will provide a new building, which will surpass that of the American Museum of Natural History in New York City and the new building for the U. S. National Museum, for which congress has recently appropriated three and a half million dollars. The report of the director of the Field Columbian Museum for last year describes important increases in the collections and improvements in their arrangement. The collections have been largely secured through sixteen expeditions sent to different parts of North America. Ethnology seems to have been specially favored, nine expeditions under the charge of Dr. George A. Dorsey and other members of the staff having made extensive collections in Oklahoma, New Mexico, Montana, California and Alaska. Two collections were also purchased, one of which contains fourteen hundred specimens from the Tlingits of Alaska. In the department of botany the herbarium has been augmented by over twenty thousand sheets, and the de-

partment of ornithology has been increased by fifteen hundred bird skins, obtained by Mr. Brenninger, largely in New Mexico, while numerous zoological specimens were obtained by Mr. Heller on the Pacific coast. Additions have also been made to the department of geology and in other directions.



VIRGINIA OR RED DEER IN WINTER.

THE TRANSVAAL ZEBRA.

Much attention has been paid to the cataloguing and exhibition of specimens, some thirty thousand entries having been made during the year, and some hundred thousand cards written. The sum of $26,000 has been spent on new cases, and many of the collections have been rearranged and new groups

have been mounted by the taxidermists. We reproduce illustrations of two of these groups prepared by Mr. Akeley. The museum has been fortunate in adding to its scientific staff Dr. S. W. Williston, the well-known paleontologist, who shares his time between the museum and the University of Chicago. The attendance during the year was 262,576, a daily average of 719. This is an increase in attendance over the preceding year of 14,000, including 2,000, in paid admissions. The museum also conducted series of well attended lecture courses and published seven additions to its scientific series.

THE TREATMENT OF TYPHOID FEVER.

The London *Times* gives an account of a paper by Dr. Macfadyen, of the Jenner Institute, communicated on March 12 by Lord Lister to the Royal Society, which as the writer says is of peculiar interest to the public because it promises an efficient prophylactic and curative treatment for typhoid fever. That dreaded disease is known to depend upon the growth and propagation within the human body of the typhoid bacillus. Dr. Macfadyen has found that by crushing the microscopic cells of that bacillus, in a manner to be presently explained, the intracellular juices can be obtained apart from the living organism, and that these juices are highly toxic. By injecting them in small and repeated doses into a living animal its blood serum is rendered powerfully antitoxic and bactericidal. That is to say, it becomes an antidote alike to the living typhoid bacteria and to the poison which may be extracted from them. Animals dosed with the protective serum and subsequently treated with lethal doses of typhoid bacteria were found to enjoy immunity from typhoid fever, while others exposed to the same infection without the previous protective treatment died of the disease. In the same way animals receiving injections of the intracellular poison without any living bacteria escaped death only when previously treated with the protective blood serum of an animal which had gone through the immunizing process. Therefore the blood serum in question is a prophylactic for typhoid fever (at least, among the inferior animals). But further experiments were made by injecting lethal doses of the poison or of the living bacteria, and subsequently injecting the protective serum after half the time required for the toxic dose to kill the animal had been allowed to elapse. In these cases the antidote overtook the poison and the animals recovered. Therefore the serum is curative of typhoid fever when already established, as well as protective against typhoid infection. It is thus demonstrated that by the careful inoculation of an animal with the juices of the dead bacteria, its blood serum can, in the case of typhoid fever, be endowed with the antidotal properties hitherto developed, as in the case of diphtheria, only by inoculation with the living bacteria. It is reasonable to suppose that what holds good in the case of one pathogenic bacterium will also hold good in the case of others. But hypothesis, however reasonable, must be verified by experiment, and the work of extracting and investigating the juices of other bacteria is now being carried on at the Jenner Institute. Should it turn out, as may be expected, that bacterial juices in general react upon the animal organism in the same way as the living bacteria which produce them, the fact can not but have a profound influence upon medical speculation and practise.

The practical advantages of the discovery are great. When, in order to obtain a protective serum, an animal is inoculated with living pathogenic bacteria, the result is always quantitatively uncertain. The seed may fall upon a highly receptive and fertile soil, and may develop effects of unexpected violence, or it may fall upon

an unusually sterile soil and fail to produce the expected results. In other words, we can not tell what will be the output of bacterial poison from a given dose of living bacteria. But the bacterial poison itself, when isolated from the living bacteria, is a definite pathogenic agent, which we can measure, dilute, and test like any other potent drug. Those who know that bacteria are so minute as to be invisible except under high microscopic powers will naturally ask by what unimaginable accuracy of grinding they can be broken up so as to release their intracellular toxins. The answer shows once more how close is the dependence of advance in one department of research upon discovery in another department apparently quite unrelated, and how impossible it is to foretell in what ways abstract inquiry may bear upon the most important practical problems. These infinitesimal organisms are crushed in liquid air, which is at once an absolutely neutral fluid and one giving the exceedingly low temperature essential for success. Thus an important step in the treatment of disease becomes possible through the previous success of efforts to reduce the most refractory gases to the liquid condition. The intense cold of liquid air has no effect upon the vitality of bacteria. After the most prolonged immersion they propagate themselves with unabated vigor as soon as they are again placed in normal conditions. But when frozen hard in liquid air these almost inconceivably minute cells are completely broken up by trituration. The completely triturated mass may be placed in the proper medium and raised to the proper temperature, but there is no sign of bacterial growth. The poisonous juices, however, remain and possess, as has just been demonstrated, the same toxic properties as when they are directly elaborated inside the human body by the living bacteria. We have, in fact, the best guarantee that nothing has happened beyond their mechanical release in the fact that at the temperature of liquid air all chemical activities are in abeyance. The mechanical disintegration of these microscopical cells at the temperature of liquid air is not so simple a matter as it may seem. For its explanation the biologist must again apply to the physicist who has furnished him with this new and potent implement.

THE BRITISH ANTARCTIC EXPEDITION.

Reuter's Agency has cabled information from New Zealand reporting that the *Morning*, relief vessel to the British Antarctic exploration ship *Discovery*, arrived at Lyttelton on March 25. She reports finding the *Discovery* on January 23 in MacMurdo Bay (Victoria Land).

Commander Scott, of the *Discovery*, supplies the following report of the voyage up to the meeting with the *Morning*. The *Discovery* entered the ice pack on January 2 or 3 in latitude 67° south. Cape Adare was reached on January 9, but from there a heavy gale and ice delayed the expedition, which did not reach Wood Bay till January 18. A landing was effected on the 20th in an excellent harbor situated in latitude 76° 30′ south. A record of the voyage was deposited at Cape Crozier on the twenty-second. The *Discovery* then proceeded along the Barrier, within a few cables' length, examining the edge and making repeated soundings. In longitude 165° the Barrier altered its character and trended northwards. Sounding here showed that the *Discovery* was in shallow water. From the edge of the Barrier high snow slopes rose to an extensive, heavily glaciated land, with occasional bare precipitous peaks. The expedition followed the coast line as far as latitude 76°, longitude 152° 30′. The heavy pack formation of the young ice caused the expedition to seek winter quarters in Victoria Land.

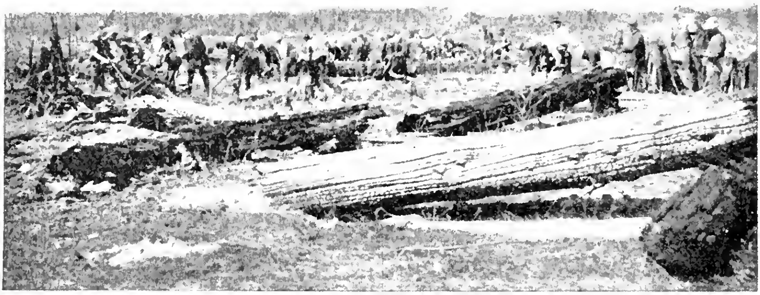
On February 3, the *Discovery* entered an inlet in the Barrier in longitude 174°. A balloon was sent up, and a sledge party examined the land as far as latitude 78° 50′. Near Mounts Erebus and Terror, at the southern extremity of an island, excellent winter quarters were found. The expedition next observed the coast of Victoria Land, extending as far as a conspicuous cape in latitude 78° 50′. It was found that mountains do not exist here, and the statement that they were to be found is clearly a matter for explanation. Huts for living and for making magnetic observations were erected, and the expedition prepared for wintering. The weather was boisterous, but a reconnaissance of sledge parties was sent out, during which the seaman Vince lost his life, the remainder of the party narrowly escaping a similar fate. The ship was frozen in on March 24. The expedition passed a comfortable winter in well sheltered quarters. The lowest recorded temperature was 62° below zero. The sledging commenced on September 2, parties being sent out in all directions. Lieutenant Royds, Mr. Skelton, and party successfully established a record in an expedition to Mount Terror, traveling over the Barrier under severe sleighing conditions, with a temperature of 58° below zero.

Commander Scott, Dr. Wilson and Lieutenant Shackleton traveled 94 miles to the south, reaching land in latitude 80° 17′ south, longitude 163° west, and establishing a world's record for the furthest point south. The journey was accomplished in most trying conditions. The dogs all died, and the three men had to drag the sledges back to the ship. Lieutenant Shackleton almost died from exposure, but is now quite recovered. The party found that ranges of high mountains continue through Victoria Land. At the meridian of 160° foothills much resembling the Admiralty Range were discovered. The ice barrier is presumably afloat. It continues horizontal, and is slowly fed from the land ice. Mountains ten or twelve thousand feet high were seen in latitude 82° south, the coast line continuing at least as far as 83° 20′ nearly due south. A party ascending a glacier on the mainland found a new range of mountains. At a height of 9,000 feet a level plain was reached unbroken to the west as far as the horizon. The scientific work of the expedition includes a rich collection of marine fauna, of which a large proportion are new species. Sea and magnetic observations were taken, as well as seismographic records and pendulum observations. A large collection of skins and skeletons of southern seals and seabirds has been made. A number of excellent photographs have been taken, and careful meteorological observations were secured. Extensive quartz and grit accumulations were found horizontally bedded in volcanic rocks. Lava flows were found in the frequently recurring plutonic rock which forms the basement of the mountains. Before the arrival of the *Morning* the *Discovery* had experienced some privation, as part of the supplies had gone bad. This accounted for the death of all the dogs. She has, however, revictualled from the *Morning*, and the explorers are now in a position to spend a comfortable winter.

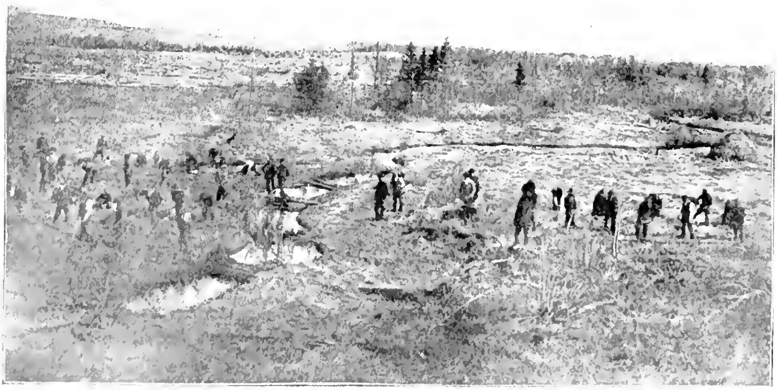
THE NEW YORK FOREST AND GAME COMMISSION.

The eighth annual report of the Forest, Fish and Game Commission of New York state, recently submitted to the legislature, shows that commendable work has been accomplished during the past year. At the beginning of the year the Adirondack reserve contained 1,325,851 acres and the Catskill reserve 82,330 acres, and to these were added 28,505 acres last year. In the Adirondack Park there are also about 700,000 acres of private reserves

and over 1,300,000 acres owned by individuals or companies. Of these lands about 1,000,000 acres are forest, about 700,000 acres lumbered, 48,000 waste, 43,000 burned, 48,000 denuded, 22,000 wild meadows, 100,000 improved and 125,000 water. During the last year reforestation was undertaken on a tract of 700 acres, the seedlings being obtained from the nurseries of the State College of Forestry. Illustrations are given showing the state of the land before reforestation. The total expenses were $2,500 or less than one half a cent a plant. Owing to the organization of fire wardens, the loss from forest fires is greatly decreasing. It amounted last year only to $9,000,



PLANTING ON BURNED LAND, ONCE COVERED WITH WHITE PINE.



PLANTING ON OLD BEAVER MEADOW NEAR LAKE CLEAR JUNCTION.

whereas in the neighboring state of New Jersey it was $168,000 and for the United States some twenty-five million dollars. It is estimated that nearly 200,000 people visited the Adirondack region last year for recreation and health.

A report is made on chestnut groves and orchards, which is not, however, very favorable to this industry. It appears that orchards in Pennsylvania have not been very successful, though groves of chestnut trees on waste mountain land may yield profitable results. A few elk and moose have been placed in the reserves, and it is believed that these animals will thrive. Pheasants have been distributed as usual and a large number of fish fry with some adults. An account is given of the shell fish industry. A hygienic examination has been made showing that the beds in Long Island Sound are removed from any possible contamination by sewage or otherwise.

SCIENTIFIC ITEMS.

PROFESSOR HENRY BARKER HILL, director of the Chemical Laboratory of Harvard College, died on April 6, in his fifty-fourth year. We regret also to record the death of Rear-Admiral George E. Belknap, retired, who, in addition to eminent services in the navy, was in charge of important hydrographic work and was at one time superintendent of the Naval Observatory; of Dr. Julius Victor Carus, associate professor of comparative zoology at Leipzig; of Dr. Franz Studnicka, professor of mathematics at Prague; of Dr. Laborde, an eminent French physician; and of Professor J. G. Wiborgh, of the Stockholm School of Mines, an authority on the metallurgy of iron.

DR. ROBERT KOCH has been elected foreign associate of the Paris Academy of Sciences, in succession to Rudolf Virchow. Dr. Koch received twenty-six votes, Dr. Alexander Agassiz eighteen votes, Dr. S. P. Langley six votes and Professor van der Waals, of Amsterdam, one vote.—The Institute of France has awarded to Dr. Emile Roux, the subdirector of the Pasteur Institute, the prize of $20,000, founded by M. Daniel Osiris, for the person that the institute considered the most worthy to be thus rewarded. Dr. Roux will give the money to the Pasteur Institute.—A committee has been formed in Paris with M. H. Moissan as chairman to strike a medal in honor of the late M. P. P. Dehérain, formerly professor of plant physiology in the University of Paris.—Mr. Joseph Larmor, fellow of St. John's College, Cambridge University, has been elected Lucasian professor of mathematics in succession to the late Sir George Gabriel Stokes.—The subject of the Silliman lectures to be given at Yale University by Professor J. J. Thomson, of Cambridge University, will be 'Present Development of Our Ideas of Electricity.' The lectures, eight in number, will begin May 14.

PRESIDENT ROOSEVELT has appointed the following as a commission to report to him on the organization, needs, and present condition of government work, with a view to including under the Department of Commerce bureaus not assigned to that department by congress: Charles D. Walcott, Department of the Interior; Brigadier-General William Crozier, War Department; Rear-Admiral Francis T. Bowles, Navy Department; Gifford Pinchot, Department of Agriculture; James R. Garfield, Department of Commerce and Labor.—Recently the President asked the Commissioner of Fish and Fisheries to have made a comprehensive and thorough investigation of the salmon fisheries of Alaska, and for this purpose Commissioner Bowers has appointed a special Alaska Salmon Commission consisting of the following: President David Starr Jordan, of Stanford University, executive head; Dr. Barton Warren Evermann, ichthyologist of the U. S. Fish Commission;

Lieutenant Franklin Swift, U. S. N., commanding officer of the *Albatross;* Cloudsley Rutter, naturalist of the *Albatross;* A. B. Alexander, fishery expert of the *Albatross;* and J. Nelson Wisner, superintendent of fish cultural stations of the U. S. Fish Commission.

THE council of the British Association for the Advancement of Science has nominated the Right Hon. Arthur James Balfour to the office of president for the Cambridge meeting in 1904. They further agreed to recommend to the association the acceptance of the invitation to South Africa for the year 1905.

THE American Philosophical Society held at Philadelphia a general meeting on April 2, 3 and 4. Numerous papers were presented, including an address on the early work of the society by Dr. Edgar F. Smith, the president, and one on 'The Carnegie Institution during the first year of its development,' by President Daniel C. Gilman. The sessions were held in the hall of the society. Luncheon was served to members on each day; there was a reception to members and ladies accompanying them on Thursday evening, and visiting members were the guests of resident members at dinner on Friday evening.—The annual stated session of the National Academy of Sciences began at Washington on April 21.—The spring meeting of the council of the American Association for the Advancement of Science was held at Washington on April 23.

THE administrative board appointed to organize and conduct the international congresses to be held in connection with the World's Fair in St. Louis in 1904, met on March 11 at the New York offices of the exhibition. There were present President Butler, of Columbia University, chairman; President Harper, University of Chicago; President Jesse, University of Missouri; Dr. Herbert Putnam, Librarian of Congress, and Frederick W. Holls, member of The Hague Tribunal. The board met to consider the report of the committee on the Congress of Arts and Science, which had been in session the two preceding days. The members of the committee met with the board. They are: Professor Simon Newcomb, Washington, chairman; Professor Hugo Münsterberg, Harvard University, and Professor Albion W. Small, University of Chicago. Mr. Howard J. Rogers, director of congresses, was also present. There is to be a 'Congress of Arts and Science,' with 128 sections. The board adjourned to meet in St. Louis on April 29.—The Swedish government has appropriated $20,000 for the publication of the scientific results of Dr. Sven Hedin's journey through central Asia. The work will comprise an atlas of two large volumes, while a third volume will contain Dr. Hedin's report on the geography of the country. Further volumes will be devoted to the meteorological observations, the astronomical observations, the geological, botanical and zoological collections, and the Chinese manuscripts and inscriptions. The work will be published in the English language.

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JUNE, 1903.

HERTZIAN WAVE WIRELESS TELEGRAPHY. I.*

By Dr. J. A. FLEMING, F.R.S.,
PROFESSOR OF ELECTRICAL ENGINEERING, UNIVERSITY COLLEGE, LONDON.

THE immense public interest which has been aroused of late years in the subject of telegraphy without connecting wires has undoubtedly been stimulated by the achievements of Mr. Marconi in effecting communication over great distances by means of Hertzian waves. The periodicals and daily journals, which are the chief avenues through which information reaches the public, whilst eager to describe in a sensational manner these wonderful applications of electrical principles, have done little to convey an intelligible explanation of them. Hence it appeared probable that a service would be rendered by an endeavor to present an account of the present condition of electric wave telegraphy in a manner acceptable to those unversed in the advanced technicalities of the subject, but acquainted at least with the elements of electrical science. It is the purpose of these articles to attempt this task. We shall, however, limit the discussion to an account of the scientific principles underlying the operation of this particular form of wireless telegraphy, omitting, as far as possible, references to mere questions of priority and development.

The practical problem of electric wave wireless telegraphy, which has been variously called Hertzian wave telegraphy, Marconi teleg-

* This series of articles is based on the Cantor lectures delivered before the Society of Arts, London, in March, 1903. The lectures were attended by many of the leading British scientific men and electrical engineers, and attracted wide attention as the most complete and authoritative statement hitherto made of wireless telegraphy. In writing the articles for The Popular Science Monthly, the author has omitted advanced technicalities in order that the substance may be suitable for the general reader.—Editor.

raphy, or spark telegraphy (*Funkentelegraphie*), is that of the production of an effect called an electric wave or train of electric waves, which can be sent out from one place, controlled, detected at another place, and interpreted into an alphabetic code. Up to the present time, the chief part of that intercommunication has been effected by means of the Morse code, in which a group of long and short signs form the letter or symbol. Some attempts have been made with more or less success to work printing telegraphs and even writing or drawing telegraphs by Hertzian waves, but have not passed beyond the experimental stage, whilst wireless telephony by this means is still a dream of the future.

We shall, in the first place, consider the transmitting arrangements and, incidentally, the nature of the effect or wave transmitted; in the second place, the receiving appliances; and finally, discuss the problem of the isolation or secrecy of the intelligence conveyed between any two places.

The transmitter used in Hertzian wave telegraphy consists essentially of a device for producing electric waves of a type which will travel over the surface of the land or sea without speedy dissipation, and the important element in this arrangement is the *radiator,* by which these waves are sent out. It will be an advantage to begin by explaining the electrical action of the radiator, and then proceed to discuss the details of the transmitting appliances.

It will probably assist the reader to arrive most easily at a general idea of the functions of the various portions of the transmitting arrangements, and in particular of the radiator, if we take as our starting point an analogy which exists between electric wave generation for telegraphic purposes and air wave generation for sound signal purposes. Most persons have visited some of the large lighthouses which exist around our coasts and have there seen a steam or air *siren,* as used for the production of sound signals during fogs. If they have examined this appliance, they will know that it consists, in the first place, of a long metal tube, generally with a trumpet-shaped mouthpiece. At the bottom of this tube there is a fixed plate with holes in it, against which revolves another similarly perforated plate. These two plates separate a back chamber or wind chest from the tube, and the wind chest communicates with a reservoir of compressed air or a high-pressure steam boiler. In the communication pipe there is a valve which can be suddenly opened for a longer or shorter time. When the movable plate revolves, the coincidence or non-coincidence of the holes in the two plates opens or shuts the air passage way very rapidly. Hence when the blast of air or steam is turned on, the flow is cut up by the revolving plates into a series of puffs which inflict blows upon the stationary air in the siren tube. If these blows come at the rate,

say of a hundred a second, they give rise to aerial oscillations in the tube, which impress the ear as a deep, musical note or roar; and this continuous sound can be cut up by closing the valve intermittently into long and short periods, and so caused to signal a letter according to the Morse code, denoting the name of the lighthouse. In this case the object is to produce: first, aerial vibrations in the tube, giving rise to a train of powerful air waves; secondly, to intermit this wave-train so as to produce an intelligible signal; and thirdly, to transmit this wave as far as possible through space.

The production of a sound or air wave can only be achieved by administering a very sudden blow to the general mass of the air in the tube. This impulse must be sufficient to call into operation the inertia and elastic qualities of the air. It is found, moreover, that the amplitude of the resulting wave, or the loudness of the sound, is increased by suitably proportioning the length of the siren pipe and the frequency of the air puffs; whilst the distance at which it is heard depends also in some degree upon the form of the mouthpiece.

Inside the siren tube, when it is in operation, the air molecules are in rapid vibratory motion in the direction of the length of the tube. If we could at any one instant examine the distribution and changes of air pressure in the tube, we should find that at some places there are large, and at others small, variations in air pressure. These latter places are called the *nodes* of pressure. At the pressure nodes, however, we should find large variations in the velocity of the air particles, and these points are called the *antinodes* of velocity. In those places at which the pressure variation is greatest, the velocity changes are least, and *vice versa*. Outside the tube, as a result of these air motions in it, we have a hemispherical air wave produced, which travels out from the mouthpiece as a center; and if we could examine the distribution of air pressure and velocity through all external space, we should find a distribution which is periodic in space as well as time, constituting the familiar phenomenon of an air wave.

Turning then to consider the production of an electric, instead of an air wave, we notice in the first place that the medium with which we are concerned is the *ether* filling all space. This ether permits the production of physical changes in it which are analogous to, but not identical in nature with, the pressures and movements which constitute a sound wave. The Hertzian radiator is an appliance for acting on the ether as the siren acts on the air. It produces a wave in it, and it can be shown that all the parts of the above described siren apparatus have their electrical equivalents in the transmitter employed in Hertzian wave wireless telegraphy.

To understand the nature of an electric wave we must consider, in the first place, some properties of the ether. In this medium we can

at any place produce a state called *electric displacement* or *ether strain,* as we can produce compression or rarefaction in air; and, just as the latter changes are said to be created by mechanical force, so the former is said to be due to *electric force.* We can not define more clearly the nature of this ether strain or displacement until we know much more about the structure of the ether than we do at present. We can picture to ourselves the operation of compressing air as an approximation of the air molecules, but the difficulty of comprehending the nature of an electric wave arises from the fact that we can not yet definitely resolve the notion of electric strain into any simpler or more familiar ideas.

We have to be content, therefore, to disguise our present ignorance by the use of some descriptive term, such as *electric strain, electrostatic strain* or *ether strain,* to describe the directed condition of the space around a body in a state of electrification which is produced by electric force. This electric strain is certainly not of the nature of a compression in the ether, but much more akin to a twist or rotational strain in a solid body.

For our present purpose it is not so necessary to postulate any particular theory of the ether as it is to possess some consistent hypothesis, in terms of which we can describe the phenomena which will concern us. These effects are, as we shall see, partly states of electrification on the surface or distributions of electric current in wires or rods, and partly conditions in the space outside them, which we are led to recognize as distributions of electric strain and of an associated effect called *magnetic flux.*

We find such a theory at hand at the present time in the electronic theory of electricity, which has now been sufficiently developed and popularized to make it useful as a descriptive hypothesis.* This theory has the great recommendation that it offers a means of abolishing the perplexing dualism of ether and ponderable matter, and gives a definite and, in a sense, objective meaning to the word electricity. In this physical speculation, the chief subject of contemplation is the electron, or ultimate particle of negative electricity, which, when associated in greater or less number with a matrix of some description, forms the atom of ponderable matter. To avoid further hypothesis, this matrix may be called the *co-electron;* and we shall adopt the view that a single chemical atom is a union of a *co-electron* with a surrounding envelope or group of electrons, one or more of the latter being detachable. We need not stop to speculate on the structure of the atomic core or co-electron, whether it is composed of positive and negative electrons or

* For a more detailed account of this hypothesis, the reader is referred to an article by the present writer entitled: 'The Electronic Theory of Electricity,' published in the POPULAR SCIENCE MONTHLY for May, 1902.

of something entirely different. The single electron is the indivisible unit or atomic element of so-called negative electricity, and the neutral chemical atom deprived of one electron is the unit of positive electricity. On this hypothesis, the chemical atom is to be regarded as a microcosm, a sort of a solar system in miniature, the component electrons being capable of vibration relatively to the atomic center of mass. Furthermore, from this point of view it is the electron which is the effective cause of radiation. It alone has a grip on the ether whereby it is able to establish wave motion in the latter.

Dr. Larmor has developed in considerable detail an hypothesis of the nature of an electron which makes it the center or convergence-point of lines of a self-locked ether strain of a torsional type. The notion of an atom merely as a 'center of force' was one familiar to Faraday and much supported by Boscovich and others. The fatal objection to the validity of this notion as originally stated was that it offers no possibility of explaining the inertia of matter. On the electronic hypothesis, the source of all inertia is the inertia of the ether, and until we are able to dissect this last quality into anything simpler than the time-element involved in the production of an ether strain or displacement, we must accept it as an ultimate fact, not more elucidated because we speak of it as the inductance of the electron.

We postulate, therefore, the following ideas: We have to think of the ether as a homogeneous medium in which a strain of some kind, most probably of a rotational type, is possible. This strain appears only under the influence of an appropriate stress called the electric force, and disappears when the force is removed. Hence to create this strain necessitates the expenditure of energy. An electron is a center or convergence-point of lines of permanent ether strain of such nature that it can not release itself. To obtain some idea of the nature of such a structure, let us imagine a flat steel band formed into a ring by welding the ends together. There is then no torsional strain. If, however, we suppose the band cut in one place, one end then given half a turn and the cut ends again welded, we shall have on the band a self-locked twist, which can be displaced on the band, but which can not release itself or be released except by cutting the ring. Hence we see that to make an electron in an ether possessing torsional elasticity would require creative energy, and when made, the electron can not destroy itself except by occupying simultaneously the same place as an electron of opposite type. Every electron extends, therefore, as Faraday said of the atom, throughout the universe, and the properties that we find in the electron are only there because they are first in the universal medium, the ether. Every line of ether or electric strain

must, therefore, be a self-closed line, or else it must terminate on an electron and a co-electron.

So far we have only considered the electron at rest. If, however, it moves, it can be mathematically demonstrated that it must give rise to a second form of ether strain which is related to the electric strain as a twist is related to a thrust or a vortex ring to a squirt in liquid or a rotation to a linear progression. The ether strain which results from the lateral movement of lines of electric strain is called the *magnetic flux,* and it can be mathematically shown that the movement of an electron, consisting when at rest of a radial convergence of lines of electric strain, must be accompanied by the production of self-closed lines of magnetic flux, distributed in concentric circles or rings round it, the planes of these circles being perpendicular to the direction of motion of the electron.

This electronic hypothesis, therefore, affords a basis on which we can build up a theory affording an explanation of the nature of the intimate connection known to exist between ether, matter and electricity. The electron is the connecting link between them all, for it is in itself a center of convergent ether strain; isolated, it presents itself as electricity of the negative or resinous kind; and, in combination with co-electrons and other electrons, it forms the atoms of ponderable matter. At rest the electron or the co-electron constitutes an electric charge, and when in motion it is an electric current. A steady flux or drift of electrons in one direction and co-electrons in the opposite direction is a continuous electric current, whilst their mere oscillation about a mean position is an alternating current. Furthermore, the vibration of an electron, if sufficiently rapid, enables it to establish what are called electric waves in the ether, but which are really detached and self-closed lines of ether strain distributed in a periodic manner through space.

We have, therefore, to start with, three conceptions concerning the electron, viz: Its condition when at rest; its state when in uniform motion; and its operations when in vibration or rapid oscillation. In the first case, by our fundamental supposition, it consists of lines of ether strain of a type called the electric strain, radiating uniformly in all directions. When in uniform motion, it can be shown that these lines of electric strain tend to group themselves in a plane perpendicular to the line of motion drawn through the electron, and their lateral motion generates another class of strain called the magnetic strain, disposed in concentric circles described round the electron and lying in this equatorial plane.

The proof of the above propositions can not be given verbally, but requires the aid of mathematical analysis of an advanced kind. The

reader must be referred for the complete demonstration to the writings of Professor J. J. Thomson* and Mr. Oliver Heaviside.†

In the third case, when the electron vibrates, we have a state in which self-closed lines of electric strain and magnetic flux are thrown off and move away through the ether, constituting electric radiation. The manner in which this happens was first described by Hertz in a paper on 'Electric Oscillations treated according to the Method of Maxwell.'‡ As this phenomenon lies at the very root of Hertzian wave wireless telegraphy, we must spend a moment or two in its careful examination.

Let us imagine two metal rods placed in line and constituting what is called a linear oscillator. Let these rods have adjacent ends separated by a very small air space, and let one rod be charged with positive and the other with negative electricity. On the electronic theory this is explained by stating that there is an accumulation of electrons in one and of co-electrons in the other. These charges create a distribution of electric strain throughout their neighborhood, which follows approximately the same law of distribution as the lines of magnetic force of a bar magnet, and may be roughly represented as in Fig. 1. Suppose then that the air gap is destroyed, these charges move towards each other and disappear by uniting, the lines of electric strain then collapse, and as they shrink in give rise to circular lines of magnetic flux embracing the rods. This external distribution of magnetism constitutes an electric current in the rods produced by the movement of the two opposite electric charges. At this stage it may be explained that the electrons or atoms of electricity can in some cases make their way freely between the atoms of ponderable matter. The former are incomparably smaller than the latter, and in those cases in which this electronic movement can take place easily, we call the material a good conductor.

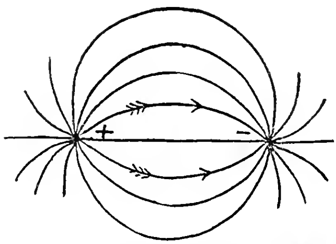


Fig. 1. Lines of Electric Strain between a Positive and Negative Electron at Rest.

Suppose then the electric charges reappear in reversed positions and go through an oscillatory motion. The result in the external space would be the alternate production of lines of electric strain and magnetic flux, the direction of these lines being reversed each half cycle.

* See J. J. Thomson, 'Recent Researches in Electricity and Magnetism,' Chapter I., 16.

† See O. Heaviside, 'Electromagnetic Theory,' Vol. I., p. 54.

‡ Wiedemann's *Annalen*, 36, p. 1, 1889. Or in his republished papers, 'Electric Waves,' p. 137. English translation by D. E. Jones.

Inside the rods we have a movement of electrons and co-electrons to and fro, electric charges at the ends of the rods alternating with electric currents in the rods, the charges being at a maximum when the current is zero, and the current at a maximum when the charges have for the moment disappeared. Outside the rods we have a corresponding set of charges, lines of electric strain stretching from end to end of the rod, alternating with rings of magnetic flux embracing the rod. So far we have supposed the oscillation to be relatively a slow one.

Imagine next that the to and fro movement of the electrons or charges is sufficiently rapid to bring into play the inertia quality of the medium. We then have a different state of affairs. The lines of strain in the external medium can not contract or collapse quickly

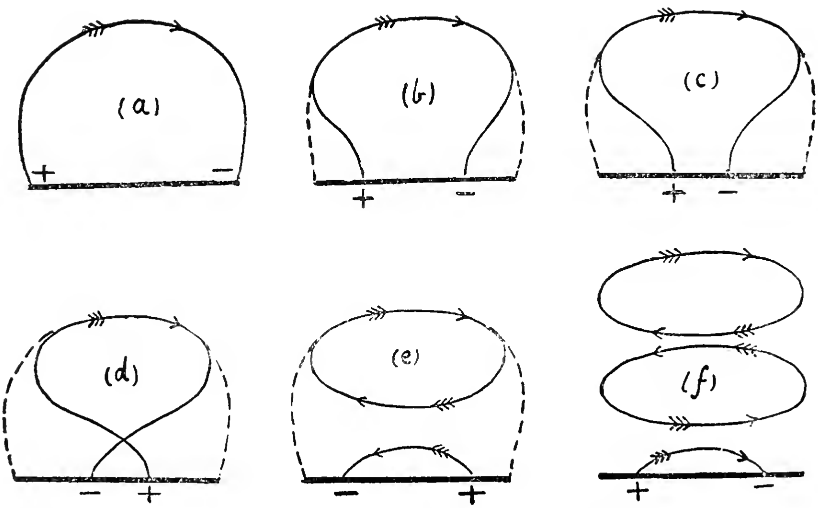


FIG. 2. SUCCESSIVE STAGES IN THE DEFORMATION OF A LINE OF STRAIN BETWEEN POSITIVE AND NEGATIVE ELECTRONS IN RAPID OSCILLATION, SHOWING CLOSED LOOP OF ELECTRIC STRAIN THROWN OFF.

enough to keep up with the course of events, or movements of the electrons in the rods, and hence their regular contraction and absorption is changed into a process of a different kind. As the electrons and co-electrons, *i. e.*, the electric charges, vibrate to and fro, the lines of electric strain connecting them are nipped in and thrown off as completely independent and closed lines of electric strain, and at each successive alternation, groups or batches of these loops of strain are detached from the rod, and, so to speak, take on an independent existence. The whole process of the formation of these self-closed lines of electric strain is best understood by examining a series of diagrams which roughly represent the various stages of the process. In Fig. 2 we have a diagram (*a*) the curved line in which delineates approxi-

mately the form of one line of electric strain round a linear oscillator, with spark gap in the center, one half being charged positively and the other negatively. Let us then suppose that the insulation of the spark gap is destroyed, so that the opposite electric charges rush together and oscillate to and fro. The strain lines at each oscillation are then crossed or decussate, and the result, as shown in Fig. 2, *d*, is that a portion of the energy of the field is thrown off in the form of self-closed lines of strain (see Fig. 2, *e*). At each oscillation of the charges the direction of the lines of strain springing from end to end of the radiator is reversed. It is a general property of lines of strain, whether electric or magnetic, that there is a tension along the line and a pressure at right angles. In other words, these lines of electric strain are like elastic threads, they tend to contract in the direction of their length and press sideways on each other when in the same direction. Hence it is not difficult to see that as each batch of self-closed lines of strain is thrown off, the direction of the strain round each loop is alternately in one direction and in the other. Hence these loops of electric strain press each other out, and each one that is formed squeezes the already formed loops further and further from the radiator. The loops, therefore, march away into space (see Fig. 2, *f*). If we imagine ourselves standing at a little distance at a point on the equatorial line and able to see these loops of strain as they pass, we should recognize a procession of loops, consisting of alternately directed strain lines marching past. This movement through the ether of self-closed lines of electric strain constitutes what is called electric radiation.

Hence along a line drawn perpendicular to the radiator through its center, there is a distribution of electric strain normal to that line, which is periodic in space and in time. Moreover, in addition to these lines of electric strain, there are at right angles to them another set of self-closed lines of magnetic flux. Alternated between the instants when the electric charges at the ends of the radiator are at their maximum, we have instants when the radiator rod is the seat of an electric current, and hence the field round it is filled with circular lines of magnetic flux coaxial with the radiator. As the current alternates in direction each half period, these rings of magnetic flux alternate in direction as regards the flux, and hence we must complete our mental picture of the space round the radiator rods when the charges are oscillating by supposing it filled with concentric rings of magnetic flux which are periodically reversed in direction, and have their maximum values at those instants and places where the lines of electric strain have their zero values. Accordingly, along the equatorial line we have two sets of strains in the ether, distributed periodically in space and in time. First, the lines of electric strain

in the plane of the radiator, and secondly, the lines of magnetic flux at right angles to these. At any one point in space these two changes, the strain and the flux, succeed each other periodically, being, however, at right angles in direction. At any one moment these two effects are distributed periodically or cyclically through space, and these changes in time and space constitute an *electric wave* or electromagnetic wave.

We may then summarize the above statements by saying that the most recent hypothesis as to the nature of electrical action and of electricity itself is briefly comprised in the following statements: The universally diffused medium called the ether has had created in it certain centers of strain or radiating points from which proceed lines of strain, and these centers of force are called electrons. Electrons must, therefore, be of two kinds, positive and negative, according to the direction of the strain radiating from the center. These electrons in their free condition constitute what we call electricity, and the electrons themselves are the atoms of electricity which, in one sense, is, therefore, as much material as that which we call ordinary gross or ponderable matter.

Collocations of these electrons constitute the atoms of gross matter, and we must consider that the individuality of any atom is not determined merely by the identity of the electrons composing it, but by the permanence of their arrangement or form. In any mass of material substance there is probably a continual exchange of electrons from one atom to another, and hence at any one given moment, whilst a number of the electrons are an association forming material atoms, there will be a further number of isolated but intermingled electrons, which are called the free electrons. In substances which we call good conductors, we must imagine that the free electrons have the power of moving freely through or between the material atoms, and this movement of the electrons constitutes a current of electricity; whilst a superfluity of electrons of either type in any one mass of matter constitutes what we call a charge of electricity. Hence an electrical oscillation, which is merely a very rapid alternating current taking place in a conductor, is on this hypothesis assumed to consist in a rapid movement to and fro of the free electrons. We may picture to ourselves, therefore, a rod of metal in which electrical oscillations are taking place, as similar to an organ pipe or siren tube in which movements of the air particles are taking place to and fro, the free electrons corresponding with the air particles.

Owing to the nature of the structure of an electron, it follows, however, that every movement of an electron is accompanied by changes in the distribution of the electric strain or ether strain taking place throughout all surrounding space, and, as already explained, certain very rapid movements of the electrons have the effect of detaching

closed lines of strain in the ether which move off through space, forming, when cyclically distributed, an electric wave.

We may next proceed to apply these principles to the explanation of the action of the simplest form of Hertzian wave telegraphic radiator, viz., the Marconi aerial wire. In its original form this consists of a long vertical insulated wire *A*, the lower end of which is attached to one of the spark balls *S* of an induction coil *I*, the other spark ball being connected to earth *E*, and the two spark balls being placed a few millimeters apart (see Fig. 3). When the coil is set in action, oscillatory or Hertzian sparks pass between the balls, electric oscillations are set up in the wire and electric waves are radiated from it. Deferring for the moment a more detailed examination of the operations of the coil and at the spark gap, we may here say that the action which takes place in the aerial wire is as follows: The wire is first charged to a high potential, let us suppose, with negative electricity. We may imagine this process to consist in forcing additional electrons into it, the induction coil acting as an electron pump. Up to a certain pressure the spark gap is a perfect insulator, but at a critical pressure, which for spark gap lengths of four or five millimeters and balls about one centimeter in diameter approximates to three thousand volts per millimeter, the insulation of the air gives way, and the charge in the wire rushes into the earth. In consequence, however, of the inertia of the medium or of the electrons, the charge, so to speak, overshoots the mark, and the wire is then left with a charge of opposite sign. This again in turn rebounds, and so the wire is discharged by a series of electrical oscillations, consisting of alternations of static charge and electric discharge. We may fasten our attention either on the events taking place in the vertical wire or in the medium outside, but the two sets of phenomena are inseparably connected and go on together. When the aerial wire is statically charged, we may describe it by saying that there is an accumulation of electrons or co-electrons in it. Outside the wire there is, however, a distribution of electric strain, the strain lines proceeding from the wire to the earth (see Fig. 4).

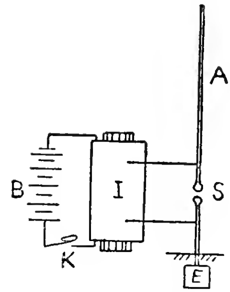


FIG. 3. SIMPLE MARCONI RADIATOR. *B*, battery; *I*, induction coil; *K*, signalling key; *S*, spark gap; *A*, aerial wire; *E*, earth plate.

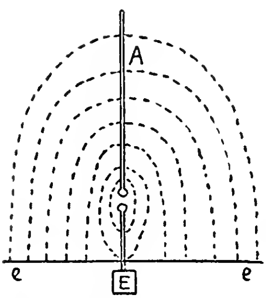


FIG. 4. LINES OF ELECTRIC STRAIN (DOTTED LINES) EXTENDING BETWEEN A MARCONI AERIAL *A* AND THE EARTH *ee* BEFORE DISCHARGE.

The wire has *capacity* with respect to the earth, and it acts like the inner coating of a Leyden jar, of which the dielectric is the air and ether around it, and the outer coating is the earth's surface. When the discharge takes place, we may consider that electrons rush out of the wire and then rush back again into it. At the moment when the electrons rush out of or into the aerial wire, we say there is an electric current flowing into or out of the wire, and this electron movement, therefore, creates the magnetic flux which is distributed in concentric circles round the wire. This current, and, therefore, motion of electrons, can be proved to exist by its heating effect upon a fine wire inserted in series with the aerial, and in the case of large aerials it may have a mean value of many amperes and a maximum value of hundreds of amperes. Inside the aerial wire we have, therefore, alternations of electric potential or charge and electric current, or we may call it electron-pressure and electron-movement.

There is, therefore, an oscillation of electrons in the aerial wire, just as in the case of an organ pipe there is an oscillation of air molecules in the pipe. Outside the aerial we have variations and distributions of electric strain and magnetic flux. The resemblance between the closed organ-pipe and the simple Marconi aerial is, in fact, very complete. In the case of the closed organ-pipe, we have a longitudinal oscillation of air molecules in the pipe. At the open end or mouthpiece, where we have air moving in and out, the air movement is alternating and considerable, but there is little or no variation of air pressure. At the upper or closed end of the pipe we have great variation of air pressure, but little or no air movement (see Fig. 5).

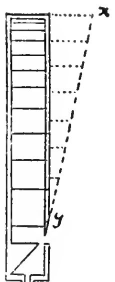


FIG. 5. AMPLITUDE OF PRESSURE VARIATION IN A CLOSED ORGAN PIPE, INDICATED BY THE ORDINATES OF THE DOTTED LINE *xy*.

Compare this now with the electrical phenomena of the aerial. At the spark ball or lower end we have little or no variation of potential or electron pressure, but we have electrons rushing into and out of the aerial at each half oscillation, forming the electric discharge or current. At the upper or insulated end we have little or no current, but great variations of potential or electron pressure. Supposing we could examine the wire inch by inch, all the way up from the spark balls at the bottom to the top, we should find at each stage of our journey that the range of variation and maximum value of the current in the wire became less and those of the potential became greater. At the bottom we have nearly zero potential or no electric pressure, but large current, and at the top end, no current, but great variation of potential.

We can represent the amplitude of the current and potential values

along the aerial by the ordinates of a dotted line so drawn that its distance from the aerial represents the potential oscillation or current oscillation at that point (see Fig. 6).

This distribution of potential and current along the wire does not necessarily imply that any one electron moves far from its normal position. The actual movement of any particular air molecule in the case of a sound wave is probably very small, and reckoned in millionths of an inch. So also we must suppose that any one electron may have a small individual amplitude of movement, but the displacement is transferred from one to another. Conduction in a solid may be effected by the movement of free electrons intermingled with the chemical atoms, but any one electron may be continually passing from a condition of freedom to one of combination.

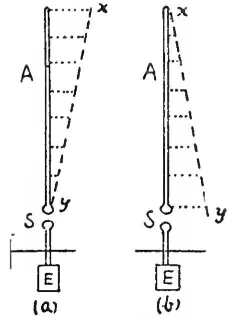


FIG. 6. (*a*) DISTRIBUTION OF ELECTRIC PRESSURE IN A MARCONI AERIAL *A*, (*b*) DISTRIBUTION OF ELECTRIC CURRENT IN A MARCONI AERIAL, AS SHOWN BY THE ORDINATES OF THE DOTTED LINE *xy*.

So much for the events inside the wire, but now outside the wire its electric charge is represented by lines of electric strain springing from the aerial to the earth. It must be remembered that every line of strain terminates on an electron or a co-electron. Hence when the discharge or spark takes place between the spark balls, the rapid movement of the electrons in the wire is accompanied by a redistribution and movement of the lines of strain outside. As the negative charge flows out of the aerial the ends of the strain lines abutting on to it run down the wire and are transferred to the earth, and at the next instant this semi-loop of electric or ether strain, with its ends on the earth, is pushed out sideways from the wire by the growth of a new set of lines of ether strain in an opposite direction. The process is best understood by consulting a series of diagrams which represent the distribution and approximate form of a few of the strain lines at successive instants (see Fig. 7). In between the lines of formation of the successive strain lines between the aerial and the earth, corresponding to the successive alternate electric charges of the aerial with opposite sign, there are a set of concentric rings of magnetic flux formed round it which are alternately in opposite directions, and these expand out, keeping step with the progress of the detached strain loops and having their planes at right angles to the latter. As the semi-loops of electric strain march outwards with their feet on the ground, these strain lines must always be supposed to terminate on electrons, but not continually on the same electrons. Since the earth is a conductor, we must suppose that there is a continual migration of the electrons forming the

atoms of the earth, and that when one electron enters an atom, another leaves it. Hence corresponding to the electric wave in the space above, there are electrical changes in the ground beneath. This view is confirmed by the well-known fact that the achievement of Hertzian wave telegraphy is much dependent on the nature of the surface over which it is conducted, and can be carried on more easily over good conducting material, like sea water, than over badly conducting dry land.

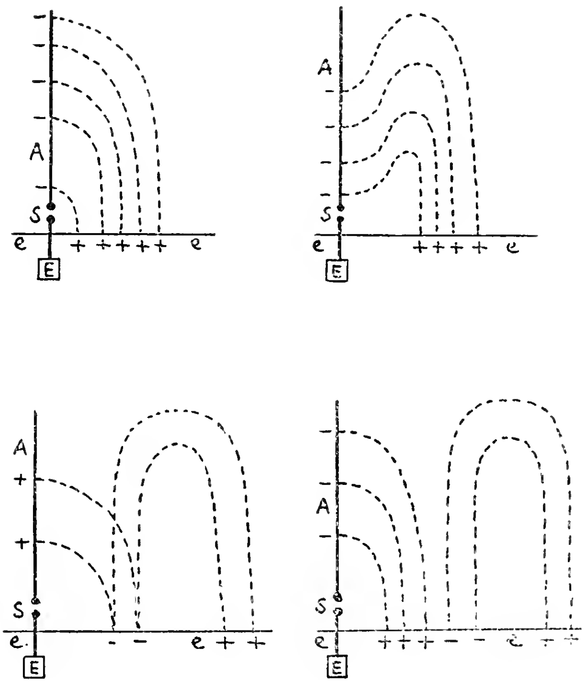


Fig. 7. Successive stages in the production of a Semi-loop of Electric Strain by a Marconi Aerial Radiator.

The matter may be viewed, however, from another standpoint. Good conductors are opaque to Hertzian waves; in other words, are non-absorptive. The energy of the electric wave is not so rapidly absorbed when it glides over a sea surface as when it is passing over a surface which is an indifferent conductor, like dry land. In fact, it is possible by the improvement of the signals to detect a heavy fall of rain in the space between two stations separated only by dry land. It is, however, clear that on the electronic theory the progression of the lines of electric strain can only take place if the surface over which they move is a fairly good conductor, unless these lines of strain form completely closed loops. Hence we may sum up by saying that there are three sets of phenomena to which we must pay attention in formu-

lating any complete theory of the aerial. The first is the operation taking place in the vertical wire, which is described by saying that electrical oscillations or vibratory movements of electrons are taking place in it, and, on our adopted theory, it may be said to consist in a longitudinal vibration of electrons of such a nature that we may appropriately call the aerial an ether organ pipe. Then in the next place, we have the distribution and movement of the lines of electric strain and magnetic flux in the space outside the wire, constituting the electric wave; and lastly, there are the electrical changes in the conductor over which the wave travels, which is the earth or water surrounding the aerial. In subsequently dealing with the details of transmitting arrangements, attention will be directed to the necessity for what telegraphists call 'a good earth' in connection with Hertzian wave telegraphy. This only means that there must be a perfectly free egress and ingress for the electrons leaving or entering the aerial, so that nothing hinders their access to the conducting surface over which the wave travels. There must be nothing to stop or throttle the rush of electrons into or out of the aerial wire, or else the lines of strain can not be detached and travel away.

We may next consider more particularly the energy which is available for radiation and which is radiated. In the original form of simple Marconi aerial, the aerial itself when insulated forms one coating or surface of a condenser, the dielectric being the air and ether around it, and the other conductor being the earth. The electric energy stored up in it just before discharge takes place is numerically equal to the product of the capacity of the aerial and half the square of the potential to which it is charged.

If we call C the capacity of the aerial in microfarads, and V the potential in volts to which it is raised before discharge, then the energy storage in joules E is given by the equation,

$$E=\frac{CV^2}{2.10^6}$$

Since one joule is nearly equal to three quarters of a foot-pound, the energy storage in foot-pounds F is roughly given by the rule $F=\frac{3}{8}\ CV^2/10^6$. For spark lengths of the order of five to fifteen millimeters, the disruptive voltage in air of ordinary pressure is at the rate of 3,000 volts per millimeter. Hence if S stands for the spark length in millimeters, and C for the aerial capacity in microfarads, it is easy to see that the energy storage in foot-pound is

$$F=\frac{27CS^2}{8}$$

If the aerial consists of a stranded wire formed of 7/22 and has a length of 150 feet, and is insulated and held vertically with its lower end near the earth, it would have a capacity of about one three ten-thousandths of a microfarad or 0.0003 mfd.* Hence if it is used as a Marconi aerial and operated with a spark gap of one centimeter in length, the energy stored up in the wire before each discharge would be only one tenth (0.1) of a foot-pound.

By no means can all of this energy be radiated as Hertzian waves; part of it is dissipated as heat and light in the spark, and yet such an aerial can, with a sensitive receiver such as that devised by Mr. Marconi, make itself felt for a hundred miles over sea in every direction. This fact gives us an idea of the extremely small energy which, when properly imparted to the ether, can effect wireless telegraphy over immense distances. Of course, the minimum telegraphic signal, say the Morse dot, may involve a good many, perhaps half a dozen, discharges of the wire, but even then the amount of energy concerned in affecting the receiver at the distant place is exceedingly small.

The problem, therefore, of long distance telegraphy by Hertzian waves is largely, though not entirely, a matter of associating sufficient energy with the aerial wire or radiator. There are obviously two things which may be done; first, we may increase the capacity of the aerial, and secondly, we may increase the charging voltage or, in other words, lengthen the spark gap. There is, however, a well-defined limit to this last achievement. If we lengthen the spark gap too much, its resistance becomes too great and the spark ceases to be oscillatory. We can make a discharge, but we obtain no radiation. When using an induction coil, about a centimeter or at most a centimeter and a half is the limiting length of oscillatory sparks; in other words, our available potential difference is restricted to 30,000 or 40,000 volts. By other appliances we can, however, obtain oscillatory sparks having a voltage of 100,000 or 200,000 volts, and so obtain what Hertz called 'active sparks' five or six centimeters in length.

Turning then to the question of capacity, we may enquire in the next place how the capacity of an aerial wire can be increased. This has generally been done by putting up two or more aerial wires in contiguity and joining them together, and so making arrangements called in the admitted slang of the subject 'multiple aerials.' The measurement of the capacity of insulated wires can be easily carried out by means of an appliance devised by the author and Mr. W. C. Clinton, consisting of a rotating commutator which alternately charges the insulated wire at a source of known electromotive force and then

* The fraction 7/22 here denotes a stranded wire formed of seven strands, each single wire having a diameter expressed by the number 22 on the British standard wire gauge.

discharges it through a galvanometer. If this galvanometer is subsequently standardized, so that the ampere value of its deflection is known, we can determine easily the capacity C of the aerial or insulated conductor, reckoned in microfarads, when it is charged to a potential of V volts, and discharged n times a second through a galvanometer. The series of discharges are equivalent to a current, of which the value in amperes A is given by the equation,

$$A = \frac{nVC}{10^6}$$

and hence if the value of the current resulting is known, we have the capacity of the aerial or conductor expressed in microfarads, given by the formula,

$$C = \frac{A10^6}{nV}$$

A series of experiments made on this plan have revealed the fact that if a number of vertical insulated wires are hung up in the air and rather near together, the electrical capacity of the whole of the wires in parallel is not nearly equal to the sum of their individual capacities. If a number of parallel insulated wires are separated by a distance equal to about 3 per cent. of their length, the capacity of the whole lot together varies roughly as the square root of their number. Thus, if we call the capacity of one vertical wire in free space, unity, then the capacity of four wires placed rather near together will only be about twice that of one wire, and that of twenty-five wires will only be about five times one wire.

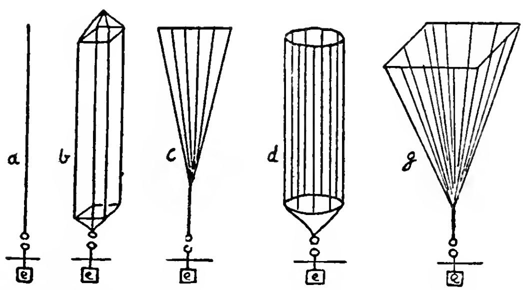


FIG. 8. VARIOUS FORMS OF AERIAL RADIATOR. *a*, Single Wire; *b*, Multiple Wire; *c*, Fan Shape; *d* Cylindrical; *g*, Conical.

This approximate rule has been confirmed by experiments made with long wires one hundred or two hundred feet in length in the open air. Hence it points to the fact that the ordinary plan of endeavoring to obtain a large capacity by putting several wires in parallel and not very far apart is very uneconomical in material. The diagrams in Fig. 8 show the various methods which have been employed

by Mr. Marconi and others in the construction of such multiple wire aerials. If, for instance, we put four insulated stranded 7/22 wires, each 100 feet long, about six feet apart, all being held in a vertical position, the capacity of the four together is not much more than twice that of a single wire. In the same manner, if we arrange 150 similar wires, each 100 feet long, in the form of a conical aerial, the wires being distributed at the top round a circle 100 feet in diameter, the whole group will not have much more than twelve times the capacity of one single wire, although it weighs 150 times as much.

The author has designed an aerial in which the wires, all of equal length, are arranged sufficiently far apart not to reduce each other's capacity.

As a rough guide in practice, it may be borne in mind that a wire about one tenth of an inch in diameter and one hundred feet long, held vertical and insulated, with its bottom end about six feet from the ground, has a capacity of 0.0002 of a microfarad, if no other earthed vertical conductors are very near it. The moral of all this is that the amount of electric energy which can be stored up in a simple Marconi aerial is very limited, and is not much more than one tenth of a joule or one fourteenth of a foot-pound, per hundred feet of 7/22 wire. The astonishing thing is that with so little storage of energy it should be possible to transmit intelligence to a distance of a hundred miles without connecting wires.

One consequence, however, of the small amount of energy which can be accumulated in a simple Marconi aerial is that this energy is almost entirely radiated in one oscillation or wave. Hence, strictly speaking, a simple aerial of this type does not create a train of waves in the ether, but probably at most a single impulse or two.

We shall later on consider some consequences which follow from this fact. Meanwhile, it may be explained that there are methods by which not only a much larger amount of energy can be accumulated in connection with an aerial, but more sustained oscillations created than by the original Marconi method. One of these methods originated with Professor Braun, of Strasburg, and a modification was first described by Mr. Marconi in a lecture before the Society of Arts of London.* In this method the charge in the aerial is not created by the direct application to it of the secondary electromotive force of an induction coil, but by means of an induced electromotive force created in the aerial by an oscillation transformer. The method due to Professor Braun is as follows: A condenser or Leyden jar has one terminal, say its inside, connected to one spark ball of an induction coil. The other spark ball is connected to the outside of the Leyden jar or

* G. Marconi, 'Syntonic Wireless Telegraphy,' *Journal of the Society of Arts*, Vol. XLIX., p. 501, 1901.

condenser through the primary coil of a transformer of a particular kind, called an oscillation transformer (see Fig. 9). The spark balls are brought within a few millimeters of each other. When the coil is set in operation, the jar is charged and discharged through the spark gap, and electrical oscillations are set up in the circuit consisting of the dielectric of the jar, the primary coil of the oscillation transformer and the spark gap. The secondary circuit of this oscillation transformer is connected in between the earth and the insulated aerial wire; hence when the oscillations take place in the primary circuit, they induce other oscillations in the aerial circuit. But the arrangement is not very effective unless, as is shown by Mr. Marconi, the two circuits of the oscillation transformer are tuned together.

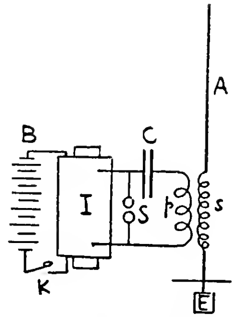


FIG. 9. MARCONI-BRAUN SYSTEM OF INDUCING ELECTROMOTIVE FORCE IN AN AERIAL *A*. *B*, battery; *K* key, *I*, induction coil; *S* spark gap; *C*, Leyden jar; *E*, earth plate; *ps*, oscillation transformer.

We shall return presently to the consideration of this form of transmitter; meanwhile, we may notice that by means of such an arrangement it is possible to create in the aerial a far greater charging electromotive force than would be the case if the aerial were connected directly to one terminal of the secondary circuit of the induction coil, the other terminal being to earth, and the two terminals connected as usual by spark balls. By the inductive arrangement it is possible to create in an aerial electromotive forces which are equivalent to a spark of a foot in length, and when the length of the aerial is also properly proportioned, the potential along it will increase all the way up, until at the top or insulated end of the aerial it may reach an amount capable of giving sparks several feet in length. From the remarks already made on the analogy between the closed organ-pipe and the Marconi aerial wire, it will be seen that the wave which is radiated from the aerial must have a wave length four times that of the aerial, if the aerial is vibrating in its fundamental manner. It is also possible to create electrical oscillations in a vertical wire which are the harmonics of the fundamental.

All musicians are aware that in the case of an organ-pipe, if the pipe is blown gently it sounds a note which is called the fundamental of the pipe. The celebrated mathematician, Daniel Bernouilli, discovered that an organ-pipe can be made to yield a succession of musical notes by properly varying the pressure of the current of air blown into it. If the pipe is an open pipe, and if we call the frequency of the primary note obtained when the pipe is gently blown, unity, then when we blow more strongly, the pipe yields notes which are the

harmonics of the fundamental one; that is to say, notes which have frequencies represented by the numbers 2, 3, 4, 5, etc. If, however, the pipe is closed at the top, then over-blowing the pipe makes it yield the odd harmonics or the tones which are related to the primary tone in the ratio of 3, 5, 7, etc., to unity. Accordingly, if a stopped pipe gives as its fundamental the note C, its first overtone will be the fifth above the octave or G′.

As already remarked, the aerial wire or radiator as used in Marconi telegraphy may be looked upon as a kind of ether organ-pipe or siren tube, and its electrical phenomena are in every respect similar to the acoustic phenomena of the ordinary closed organ-pipe. When the aerial is sounding its fundamental ether note, the conditions which pertain are that there is a current flowing into the aerial at the lower end, but at that point the variation in potential is very small, whereas at the upper end there is no current but the variations of potential are very large. Accordingly, we say that at the upper end of the aerial there is an antinode of potential and a node of current, and at the bottom, an antinode of current and a node of potential. By altering the frequency of the electrical impulses we can create in the aerial an arrangement of nodes of current or potential corresponding to the overtones of a closed organ-pipe. But whatever may be the arrangement, the conditions must always hold, that there is a node of current at the upper end and an antinode of current at the lower end. In other words, there are large variations of current at the place where the aerial terminates on the spark gap and no current at the upper end. The first harmonic is formed where there is a node of potential at one third of the length of the aerial from the top. In this case, we have a node of potential not only at the lower end of the wire, but at two thirds of the way up. In the same way we can create in the closed organ-pipe by properly overblowing the pipe, a region about two thirds of the way up the pipe, where the pressure changes in the air are practically no greater than they are at the mouthpiece. We can make evident visually in a beautiful manner the existence of similar stationary electrical waves in an aerial by means of an ingenious arrangement devised by Dr. Georg Seibt, of Berlin. It consists of a very long, silk covered copper wire *A* (see Fig. 10) wound in a close spiral of single layer round a wooden rod six feet long and about two inches in diameter. This rod is insulated, and at the lower end the wire is connected to a Leyden jar circuit, consisting of a Leyden jar or jars and an inductance coil *L*, the inductance of which can be varied. Oscillations are set up in this jar circuit by means of an induction coil discharge, and the lower end of the long spiral wire is attached to one point on the jar circuit. In this manner we can communicate to the bottom end of the long spiral wire a series of electric

impulses, the time period of which depends upon the capacity of the jar and the inductance of the discharge circuit. We can, moreover, vary this frequency over wide limits. Parallel to the long spiral wire is suspended another copper wire E (see Fig. 10), and between this wire and the silk-covered copper wire discharges take place due to the potential difference between each part of the wire and this long aerial wire. If we arrange matters so that the impulses communicated to the bottom end of the long spiral wire correspond to its fundamental note or periodic time, then in a darkened room we shall see a luminous glow or discharge between the vertical wire and the spiral wire, which increases in intensity all the way up to the top of the spiral wire. The luminosity of this brush discharge at any point is evidence of the potential of the spiral wire at that point, and its distribution clearly demonstrates that the difference of potential between the spiral wire and the aerial increases all the way up from the bottom to the top of the spiral wire. In the next place, by making a little adjustment and by varying the inductance of the jar circuit, we can increase the frequency of the impulses which are falling upon the spiral wire; and then it will be noticed that the distribution of the brush discharge or luminosity is altered, and that there is a maximum now at about one third of the height of the spiral wire, and a dark place at about two thirds of the height, and another bright place at the top, thus showing that we have a node of potential at about two thirds the way up the wire (see Fig. 11), and we have therefore set up in the spiral wire electrical oscillations corresponding to the first overtone. It is possible to show in the same way the existence of the second harmonic in the coil, but the luminosity then becomes too faint to be seen at a distance.

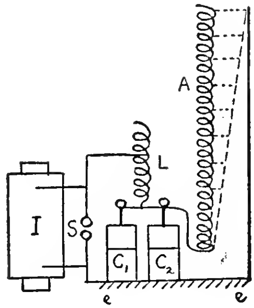


FIG. 10. SEIBT'S APPARATUS FOR SHOWING STATIONARY WAVES IN LONG SOLENOID A. I, induction coil; S, spark gap L, inductance coil; $C_1 C_2$, Leyden jars; E, earth wire.

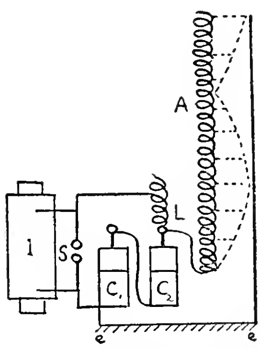


FIG. 11. HARMONIC OSCILLATIONS IN LONG SOLENOID SHOWN WITH SEIBT'S APPARATUS.

An interesting form of aerial devised by Professor Slaby, of Berlin, depends for its action entirely on the fact that the electrical oscillations set up in it which radiate are harmonics of the fundamental tone.

A closed vertical loop A_1A_2 (see Fig. 12) is formed by erecting two parallel insulated wires vertically a few feet apart and joining them together at the top. At the bottom these wires are connected, with the secondary terminals of an induction coil, a condenser C or Leyden jar being bridged across the terminals and a pair of spark balls S inserted in one side of the loop. It will readily be seen that on setting the coil in action, oscillations will take place in these vertical wires, but that if the oscillations are simply the fundamental note of the system, then at any moment corresponding to a current going up one side of the loop of wire, there must be a current coming down the other. Accordingly, an arrangement of this kind, forming what is called a closed circuit, will not radiate or radiates but very feebly. Professor Slaby found, however, that it might be converted into a powerful radiator if we give the two sides of the loop unequal capacity or inductance, and at the same time earth one of the lower ends of the loop, as shown in Fig. 13. By this means it is possible to set up in the loop electrical overtones or harmonics of the fundamental oscillation, and if we cause the system to vibrate so as to produce its first odd harmonic, there is a potential node at the lower end of both vertical sides of the loop, a potential node on both vertical sides at two thirds of the way up, and a potential antinode at the summit of the loop; then, under these circumstances, the closed loop of wire is in the same electrical condition as if two simple Marconi aerials, both emitting their first odd harmonic oscillation, were placed side by side and joined together at the top.

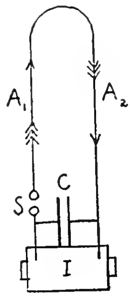


FIG. 12 NON-RADIATIVE CLOSED LOOP AERIAL.

It is a little difficult without the employment of mathematical analysis to explain precisely the manner in which earthing one side of the loop or making the loop unsymmetrical as regards inductance has the effect of creating overtones in it. The following rough illustration may, however, be of some assistance. Imagine a long spiral metallic spring supported horizontally by threads. Let this represent a conductor, and let any movement to or fro of a part of the spring represent a current in that conductor. Suppose we take hold of the spring at one end, we can move it bodily to and fro as a whole. In this case, every part of the spring is moving one way or the other in the same manner at the same time. This corresponds with the case in which the discharge of the condenser through the uniform loop con-

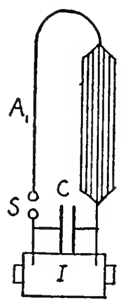


FIG. 13. SLABY'S LOOP RADIATOR.

ductor is a flow of electricity, all in one direction one way or the other. The current is in the same direction in all parts of the loop at the same time, and, therefore, if the current is going up one side of the loop it is at the same time coming down the other side. Hence the two sides of the loop are always in exact opposition as regards the effect of the current in them on the external space, and the loop does not radiate. Returning again to the case of the spring. Supposing that we add a weight to one end of the spring by attaching to it a metal ball, and then move the other end to and fro with certain periodic motion, it will be found quite easy to set up in the spring a pulsatory motion resembling the movement of the air in an open organ-pipe. Under these circumstances both ends of the spring will be moving inwards or outwards at the same time, and the central portions of the spring, although being pressed and expanded slightly, are moving to and fro very little. This corresponds in the case of the looped aerial with a current flowing up or down both sides at the same time; in other words, when this mode of electrical oscillation is established in the loop, its electrical condition is just that of two simple Marconi aerials joined together at the top and vibrating in their fundamental manner. Accordingly, if one side of the double loop is earthed, we then have an arrangement which radiates waves. Professor Slaby found that by giving one side of the loop less inductance than the other, and at the same time earthing the side having greater inductance at the bottom, he was able to make an arrangement which radiated, not in virtue of the normal oscillations of the condenser, but in virtue of the harmonic oscillations set up in the conductor itself. The mathematical theory of this radiator has been very fully developed by Dr. Georg Seibt.

It will be seen, therefore, that there are several ways in which we may start into existence oscillations in an aerial. First, the aerial may be insulated, and we may charge it to a high potential and allow this charge suddenly to rush out. Although this process gives rise to a disturbance in the ether, as already explained, it is analogous to a pop or explosion in the air, rather than to a sustained musical note. The exact acoustic analogue would be obtained if we imagine a long pipe pumped full of air and then suddenly opened at one end. The air would rush out, and, communicating a blow to the outer air, would create an atmospheric disturbance appreciated as a noise or small explosion. This is what happens when we cut the string and let the cork fly out from a bottle of champagne. At the same time, the inertia of the air rushing out of the tube would cause it to overshoot the mark, and a short time after opening the valve the tube, so far from containing compressed air, would contain air slightly rarefied near its mouth, and this rarefication would travel back up the tube in the form of

wave motion, and, being reflected as condensation at the closed end, travel down again; and so after being reflected once or twice at the open or closed end, become damped out very rapidly in virtue of both air friction and the radiation of the energy. In the case, however, of the ordinary organ-pipe, we do not depend merely upon a store of compressed air put into the pipe, but we have a store of energy to draw upon in the form of the large amount of compressed air contained in a wind chest, which is being continually supplied by the bellows. This store of compressed air is fed into the organ-pipe with the result that we obtain a continuous radiation of sound waves. The first case, in which the only store of energy is the compressed air originally contained in the pipe, illustrates the operation of the simple Marconi aerial. The second case, in which there is a larger store of energy to draw upon, the organ-pipe being connected to a wind chest, illustrates the Marconi-Braun method in which an aerial is employed to radiate a store of electric energy contained in a condenser, gradually liberated by the aerial in the form of a series of electrical oscillations and waves. In this arrangement the condenser corresponds to the wind chest, and it is continually kept full of electrical energy by means of the induction coil or transformer, which answers to the bellows of the organ. From the condenser, electrical energy is discharged each time the spark discharge passes at a spark gap in the form of electrical oscillations set up in the primary circuit of an oscillation transformer. The secondary circuit of this transformer is connected in between the earth and the aerial, and therefore may be considered as part of it, and, accordingly, the energy which is radiated from the aerial is not simply that which is stored up in it in virtue of its own small capacity, but that which is stored up in the much larger capacity represented by the primary condenser or, as it may be called, the electrical wind chest. By the second arrangement we have therefore the means of radiating more or less continuous trains of electric waves, corresponding with each spark discharge. To create powerful oscillations in the aerial, one condition of success is that there shall be an identity in time-period between the circuit of the aerial and that of the primary condenser. The aerial is an open circuit which has capacity with respect to the earth, and it has also inductance, partly due to the wire of the aerial and partly due to the secondary circuit of the oscillation transformer in series with it. The primary circuit or spark circuit has capacity, viz., the capacity of the energy-storing condenser, and it has also inductance, viz., the inductance of the primary circuit of the oscillation transformer. We shall consider at a later stage more particularly the details of syntonising arrangements, but meanwhile it may be said that one condition for setting up powerful waves by means of the above arrangement is

that the electrical time-period of both the two circuits mentioned shall be the same. This involves adjusting the inductance and capacity so that the product of conductance and capacity for each of these two circuits is numerically the same. Instead of employing an oscillation transformer between the condenser circuit and the aerial, the aerial may be connected directly to some point on the condenser circuit at which the potential oscillations are large, and we have then another arrangement devised by Professor Braun (see Fig. 14). In this case, in order to accumulate large potential oscillations at the top of the aerial, it is, as we have seen, necessary that the length of the aerial shall be one quarter the length of the wave. If therefore the electrical oscillations in the condenser circuit are at the rate of N per second, in other words, have a frequency N, the wave-length corresponding to this frequency is given by the expression,

$$3 \times 10^{10}/N \text{ cms.}$$

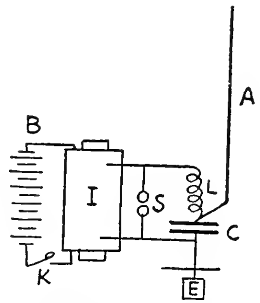


FIG. 14. BRAUN'S RADIATOR. *B*, battery; *I*, induction coil; *K*, key; *S*, spark gap; *L*, inductance coil; *C*, condenser *A*, aerial.

The number 3×10^{10} is the value in centimeters per second of the velocity of the electromagnetic wave, and is identical with that of light. The corresponding resonant length of the aerial is therefore one fourth of this wave-length, or $3 \times 10^{10}/4N$. Generally speaking, however, it will be found that with any length of aerial which is practicable, say 200 feet or 6,000 cms., this proportion necessitates rather a high frequency in the primary oscillation circuit. In the case considered, viz., for an aerial 200 feet in height, the oscillations in the primary circuit must have a frequency of one and a quarter million. This high frequency can only be obtained either by greatly reducing the inductance of the primary discharge circuit, or reducing the capacity. If we reduce the capacity, we thereby greatly reduce the storage of energy, and it is not practicable to reduce the inductance below a certain amount.

Summing up, it may be said that there are three, and as far as the writer is aware, at present only three, modes of exciting the electrical oscillations in an aerial wire. First, the aerial may itself be used as an electrical reservoir and charged to a high potential and suddenly discharged to the earth. This is the original Marconi method. The second method, due to Braun, consists of attaching the aerial to some point on an oscillation circuit consisting of a condenser, an inductance coil and a spark gap, in series with one another, and charging and

discharging the condenser across the spark gap so as to create alterations of potential at some point on the oscillation circuit. The length of the aerial must then be so proportioned as above described that it is resonant to this frequency. Thirdly, we may employ the arrangement involving an oscillation transformer, in which the oscillations in the primary condenser circuit are made to induce others in the aerial circuit, the time-period of the two circuits being the same. This method may be called the Braun-Marconi method. Professor Slaby has combined together in a certain way the original Marconi simple aerial with the resonant quarter-wave-length wire of Braun. He constructs what he calls a *multiplicator,* which is really a wire wound into a loose spiral connected at one point to an oscillation circuit consisting of a condenser inductance, the length of this wire being proportioned so that there is a great resonance or multiplication of tension or potential at its free end. This free end is then attached to the lower end of an ordinary Marconi aerial, and serves to charge it with a higher potential than could be obtained by the use of the induction coil directly attached to it.

(To be continued.)

PHYSIOLOGICAL ECONOMY IN NUTRITION.

BY RUSSELL H. CHITTENDEN,

DIRECTOR OF THE SHEFFIELD SCIENTIFIC SCHOOL OF YALE UNIVERSITY.

AMONG the many problems awaiting solution, none is of greater importance for the welfare of the individual and of the race than that which relates to the proper nutrition of the body. Man eats to live and to gain strength for his daily work, and without sufficient nutriment the machinery of the body can not be run smoothly or with proper efficiency. The taking of an excess of food, on the other hand, is just as harmful as insufficient nourishment, involving as it does not only wasteful expenditure, but what is of even greater moment, an expenditure of energy on the part of the body, which may in the long run prove disastrous. While it is the function of food to supply the material from which the body can derive the necessary energy for its varied activities, any excess of food over and above what is needed to make good the loss incidental to life and daily activity is just so much of an incubus, which is bound to detract from the smooth running of the machinery and to diminish the fitness of the body for performing its normal functions.

A proper physiological condition begets a moral, mental and physical fitness which can not be attained in any other way. Further, it must be remembered that lack of a proper physiological condition of the body is more broadly responsible for moral, social, mental and physical ills than any other factor that can be named. Poverty and vice on ultimate analysis may often be traced to a perversion of nutrition. A healthy state of the body is a necessary concomitant of mental and moral vigor, as well as of physical strength. Abnormal methods of living are often the accompaniment or forerunner of vicious tastes that might never have been developed under more strictly physiological conditions. Health, strength (mental and physical) and moral tone alike depend upon the proper fulfilment of the laws of nature, and it is the manifest duty of a people hoping for the fullest development of physical, mental and moral strength to ascertain the character of these laws with a view to their proper observance. Poverty, crime, physical ills and a blunted or perverted moral sense are the penalties we may be called upon to pay for the disobedience of nature's laws; penalties which not only *we* may have to pay, but which may be passed down to succeeding generations, thereby influencing the lives of those yet unborn.

There is to-day great need for a thorough physiological study of

those laws of nutrition which constitute the foundation of good living. It is a subject full of interest and promise for the sociologist and economist, as well as for the physiologist. We need a far more complete knowledge than we possess at present of the laws governing nutrition; we need fuller knowledge of the methods by which the most complete, satisfactory and economical utilization of the diet can be obtained; we need to know more concerning the minimum diet and the minimum amount of proteid or albuminous foods on which health, mental and physical vigor can be permanently maintained; we need to know more fully concerning the influence of various forms of food on growth and recuperative power; we need more complete knowledge regarding the rôle of various dietetic and digestive habits, fixed or acquired; the effects of thorough mastication, insalivation and the influence of two versus three meals a day upon the utilization of food and hence upon the bodily health. Further, we need more concise information as to the effect of the mental state upon digestion and nutrition. These and many other problems of a like nature confront us when we attempt to trace the influence of a proper nutrition upon the condition of the body. These problems, however, all admit of solution, and in their solution undoubtedly lies the remedy for many of the personal ills of mankind.

The foregoing thoughts have been suggested by observations recently made in the writer's laboratory on the amount and character of the food actually required by a healthy man in the maintenance of bodily equilibrium in periods of rest and physical work. Our ideas at present are based primarily upon observations as to what civilized peoples are accustomed to do, and not upon what they need to do in order to meet the demands made upon the body. Sir William Roberts has well said that the palate is the dietetic conscience, but he adds that there are many misfit palates, and we may well query whether our dietetic consciences have not become generally perverted through a false mode of living. The well-nigh universal habit of catering to our appetite on all occasions, of bowing to the fancied dictates of our palates even to the extent of satiety, and without regard to the physiological needs of the body, may quite naturally have resulted in a false standard of living in which we have departed widely from the proper laws of nutrition. Statistical studies carried out on large groups of individuals by various physiologists have led to the general acceptance of dietary standards, such as those proposed by Voit of Munich, and Atwater in this country. Thus the Voit diet for a man doing moderate work is 118 grams of proteid or albuminous food, 56 grams of fat and 500 grams of carbohydrates, such as sugar and starch, with a total fuel value of 3,055 large calories or heat units per day. With hard work, Voit increases the daily requirement to 145 grams of proteid, 160 grams of fat and 450 grams of carbohydrates, with a total

fuel value of 3,370 large calories. Atwater, on the other hand, from his large number of observations, is inclined to place the daily proteid requirement at 125 grams, with sufficient fat and carbohydrate to equal a total fuel value of 3,500 large calories for a man doing a moderate amount of work; while for a man at hard work the daily diet is increased to 150 grams of proteid, and with fats and carbohydrates to yield a total fuel value of 4,500 large calories. These standards are very generally accepted as being the requirement for the average individual under the given conditions of work, and it may be that these figures actually represent the daily needs of the body. Suppose, on the other hand, that we have in these figures false standards, or, in other words that the quantities of foodstuffs called for are altogether larger than the actual demands of the body require. In this case there is a positive waste of valuable food material which we may calculate in dollars and cents; a loss of income incurred daily which might be expended more profitably in other directions. To the wage-earner with a large family, who must of necessity husband his resources, there is in our hypothesis a suggestion of material gain not to be disregarded. The money thus saved might be expended for the education of the children, for the purchase of household treasures tending to elevate the moral and mental state of the occupants, or in many other ways that the imagination can easily supply. This kind of saving, however, is purely a question of economy, and in some strata of society would be objected to as indicative of a condition of sordidness. It has come to be a part of our personal pride to have a well-supplied table, and to eat largely and freely of the good things provided. The poorer man takes pride in furnishing his family with a diet rich in expensive articles of food, and imagines that by so doing he is inciting them to heartier consumption and to increased health and strength. He would be ashamed to save in this way, under the honest belief that by so doing he might endanger the health of his dear ones. But let us suppose that this hypothetical waste of food is not merely uneconomical, that it is undesirable for other and weightier reasons. Indeed, let us suppose that this unnecessary consumption of food is distinctly harmful to the body, that it is physiologically uneconomical, and that in our efforts to maintain a high degree of efficiency we are in reality putting upon the machinery of the body a heavy and entirely uncalled for strain which is bound to prove more or less detrimental. If there is truth in this assumption, our hypothesis takes on a deeper significance, and we may well inquire whether there are any reasonable grounds for doubting the accuracy of our present dietary standards.

In this connection it is to be remembered that the food of mankind may be classified under three heads, viz., *proteid or albuminous,* such as meat, eggs, casein of milk, gluten of bread and various vege-

table proteids; *carbohydrates,* as sugar and the starches of our cereals, and *fats,* including those of both animal and vegetable origin. The proteids are characterized by containing nitrogen (about 16 per cent.), while the fats and carbohydrates contain only carbon, hydrogen and oxygen. The two latter classes of foodstuffs are burned up in the body, when completely utilized, to carbonic acid (a gas) and water, while the proteid foods beside yielding carbonic acid and water give off practically all of their nitrogen in the form of crystalline nitrogenous products in the excreta of the body. Proteid foods have a particular function to perform, viz., to supply the waste of proteid matter from the active tissues of the body, and this function can be performed only by the proteid foods, hence the latter are essential foodstuffs without which the body can not long survive. Fats and carbohydrates, on the other hand, are mainly of value for the energy they yield on oxidation, and in this connection it is to be remembered that the fuel value of fats per gram is much larger than that of carbohydrates, viz., 9.3:4.1, or more than twice as great. Further, it is to be noted that the various foodstuffs can not be utilized directly by the body, but they must first be digested, then absorbed and assimilated, after which they gradually, in their changed form, undergo decomposition with liberation of their contained energy which may manifest itself in the form of heat or of mechanical work. The thoroughness with which foods are digested and utilized in the body must therefore count for a great deal in determining their dietetic or nutritive value. Moreover, it is easy to see how an excess of proteid food will give rise to a large proportion of nitrogenous waste matter, which floating through the system prior to excretion may by acting on the nervous system and other parts of the body produce disagreeable results. A mere excess of food, even of the non-nitrogenous variety, must entail a large amount of unnecessary work, thereby using up a proportional amount of energy for its own disposal, since once introduced into the body it must be digested and absorbed, otherwise it undergoes fermentation and putrefaction in the stomach and intestines, causing countless troubles. When absorbed in quantities beyond the real needs of the body, it may be temporarily deposited as fat, but why load up the system with unnecessary material, thereby interfering with the free running of the machinery? In other words, it is very evident that the taking in of food in quantities beyond the physiological requirements is undesirable and may prove exceedingly injurious. It is truly uneconomical and defeats the very ends we aim to attain. Instead of adding to the bodily vigor and increasing the fitness of the organism to do its daily work, we are really hampering the delicate mechanism upon the smooth running of which so much depends.

Why now should we assume that a daily diet of over 100 grams of proteid, with fats and carbohydrates sufficient to make up a fuel

value of over 3,000 large calories, is a necessary requisite for bodily vigor and physical and mental fitness? Mainly because of the supposition that true dietary standards may be learned by observing the relative amounts of nutrients actually consumed by a large number of individuals so situated that the choice of food is unrestricted. But this does not constitute very sound evidence. It certainly is not above criticism. We may well ask ourselves whether man has yet learned wisdom with regard tò himself, and whether his instincts or appetites are to be entirely trusted as safe guides to follow in the matter of his own nutrition. The experiments of Kumagawa, Sivén and other physiologists, have certainly shown that men may live and thrive, for a time at least, on amounts of proteid per day equal to only one half and one quarter the amount called for in the Voit standard. Sivén's experiments, in particular, certainly indicate that the human organism can maintain itself in nitrogenous equilibrium with far smaller amounts of proteid in the diet than is ordinarily taught, and further, that this condition can be attained without unduly increasing the total calories of the food intake. Such investigations, however, have always called forth critical comment from writers on nutrition, indicating a reluctance to depart from the current doctrines of the Voit or Munich school, and, indeed, it may justly be claimed that the ordinary nutrition experiments, extending over short periods of time, are not entirely adequate to prove the effect of a given set of conditions when the latter are continued for months or years. Thus, Schäfer writes: "It may be doubted whether a diet which includes considerably less proteid than 100 grams for the twenty-four hours could maintain a man of average size and weight for an indefinite time. It has frequently been asserted that many Asiatics consume a very much smaller proportion of proteid than is the case with Europeans. The inhabitants of India, Japan and China chiefly consume rice as the normal constituent of their diet, which contains relatively little proteid; and this has been advanced as an argument in favor of the view that the minimal amount of proteid is much less than that ordinarily given as essential to the maintenance of nutritive equilibrium. It must, however, be stated that we have no definite statistics to show that, in proportion to their body-weight, Asiatics doing the same amount of work as Europeans require a less amount of proteids; indeed such evidence as is forthcoming is rather in favor of the opposite view." This statement is typical of the attitude of physiologists in general on this important subject. Why not candidly admit that the matter is in doubt, and with a due recognition of the importance of the subject attempt to ascertain the real truth of the matter?

The writer has had in his laboratory for several months past a gentleman (H. F.) who has for some five years, in pursuit of a study

of the subject of human nutrition, practised a certain degree of abstinence in the taking of food and attained important economy with, as he believes, great gain in bodily and mental vigor and with marked improvement in his general health. Under his new method of living he finds himself possessed of a peculiar fitness for work of all kinds and with freedom from the ordinary fatigue incidental to extra physical exertion. In using the word abstinence possibly a wrong impression is given, for the habits of life now followed have resulted in the disappearance of the ordinary craving for food. In other words, the gentleman in question fully satisfies his appetite, but no longer desires the amount of food consumed by most individuals.

For a period of thirteen days, in January, he was under observation in the writer's laboratory, his excretions being analyzed daily with a view to ascertaining the exact amount of proteid consumed. The results showed that the average daily amount of proteid metabolized was 41.25 grams, the body-weight (165 pounds) remaining practically constant. Especially noteworthy also was the very complete utilization of the proteid food during this period of observation. It will be observed here that the daily amount of proteid food taken was less than one half that of the minimum Voit standard, and it should also be mentioned that this apparent deficiency in proteid food was not made good by any large consumption of fats or carbohydrates. Further, there was no restriction in diet. On the contrary, there was perfect freedom of choice, and the instructions given were to follow his usual dietetic habits. Analysis of the excretions showed an output of nitrogen equal to the breaking down of 41.25 grams of proteid per day, as an average, the extremes being 33.06 grams and 47.05 grams of proteid.

In February, a more thorough series of observations was made, involving a careful analysis of the daily diet, together with analysis of the excreta, so that not alone the proteid consumption might be ascertained, but likewise the total intake of fats and carbohydrates. The diet consumed was quite simple, and consisted merely of a prepared cereal food, milk and maple sugar. This diet was taken twice a day for seven days, and was selected by the subject as giving sufficient variety for his needs and quite in accord with his taste. No attempt was made to conform to any given standard of quantity, but the subject took each day such amounts of the above foods as his appetite craved. Each portion taken, however, was carefully weighed in the laboratory, the chemical composition of the food determined, and the fuel value calculated by the usual methods.

The following table gives the daily intake of proteids, fats and carbohydrates for six days, together with the calculated fuel value, and also the nitrogen intake, together with the nitrogen output through the excreta. Many other data were obtained showing diminished

excretion of uric acid, ethereal sulphates, phosphoric acid, etc., but they need not be discussed here.

	Intake.					Output of Nitrogen.		
	Proteids.	Fats.	Carbohy.	Calories.	Nitrogen.	Urine.	Fæces.	Total.
	Grams.	Grams.	Grams.		Grams.	Grams.	Grams.	Grams.
Feb. 2	31.3	25.3	125.4	900	5.02	5.27	0.18	5.45
3	46.8	40.4	266.2	1690	7.50	6.24	0.81*	7.05
4	48.0	38.1	283.0	1747	7.70	5.53	0.81*	6.34
5	50.0	40.6	269.0	1711	8.00	6.44	0.81*	7.25
6	47.0	41.5	267.0	1737	7.49	6.83	0.81*	7.64
7	46 5	39.8	307.3	1852	7.44	7.50	0.17	7.67
Daily Av.	44.9	38.0	253.0	1606	7.19	6.30	0.60	6.90

The main things to be noted in these results are, first, that the total daily consumption of proteid amounted on an average to only 45 grams, and that the fat and carbohydrate were taken in quantities only sufficient to bring the total fuel value of the daily food up to a little more than 1,600 large calories. If, however, we eliminate the first day, when for some reason the subject took an unusually small amount of food, these figures are increased somewhat, but they are ridiculously low compared with the ordinarily accepted dietary standards. When we recall that the Voit standard demands at least 118 grams of proteid and a total fuel value of 3,000 large calories daily, we appreciate at once the full significance of the above figures. But it may be asked, was this diet at all adequate for the needs of the body—sufficient for a man weighing 165 pounds? In reply, it may be said that the appetite was satisfied and that the subject had full freedom to take more food if he so desired. To give a physiological answer, it may be said that the body-weight remained practically constant throughout the seven days' period, and further, it will be observed by comparing the figures of the table that the nitrogen of the intake and the total nitrogen of the output were not far apart. In other words, there was a close approach to what the physiologist calls nitrogenous equilibrium. In fact, it will be noted that on several days the nitrogen output was slightly less than the nitrogen taken in. We are, therefore, apparently justified in saying that the above diet, simple though it was in variety, and in quantity far below the usually accepted requirement, was quite adequate for the needs of the body. In this connection it may be asked, what were the needs of the body during this seven days' period? This is obviously a very important point. Can a man on such a diet, even though it suffices to keep up body-weight and apparently also physiological equilibrium, do work to any extent? Will there be under such condition a proper degree of fitness for physical work of any kind? In order to ascertain this

* Average of the four days.

point, the subject was invited to do physical work at the Yale University Gymnasium and placed under the guidance of the director of the gymnasium, Dr. William G. Anderson. The results of the observations there made are here given, taken verbatim from Dr. Anderson's report to the writer.

On the 4th, 5th, 6th and 7th of February, 1903, I gave to Mr. Horace Fletcher the same kind of exercises we give to the Varsity Crew. They are drastic and fatiguing and can not be done by beginners without soreness and pain resulting. The exercises he was asked to take were of a character to tax the heart and lungs as well as to try the muscles of the limbs and trunk. I should not give these exercises to Freshmen on account of their severity.

Mr. Fletcher has taken these movements with an ease that is unlooked for. He gives evidence of no soreness or lameness and the large groups of muscles respond the second day without evidence of being poisoned by Carbon dioxide. There is no evidence of distress after or during the endurance test, *i. e.*, the long run. The heart is fast but regular. It comes back to its normal beat quicker than does the heart of other men of his weight and age.

The case is unusual and I am surprised that Mr. Fletcher can do the work of trained athletes and not give marked evidences of over exertion. As I am in almost constant training I have gone over the same exercises and in about the same way and have given the results for a standard of comparison. [The figures are not given here.]

My conclusion given in condensed form is this. Mr. Fletcher performs this work with greater ease and with fewer noticeable bad results than any man of his age and condition I have ever worked with.

To appreciate the full significance of this report, it must be remembered that Mr. Fletcher had for several months past taken practically no exercise other than that involved in daily walks about town.

In view of the strenuous work imposed during the above four days, it is quite evident that the body had need of a certain amount of nutritive material. Yet the work was done without apparently drawing upon any reserve the body may have possessed. The diet, small though it was, and with only half the accepted requirement in fuel value, still sufficed to furnish the requisite energy. The work was accomplished with perfect ease, without strain, without the usual resultant lameness, without taxing the heart or lungs, and without loss of body-weight. In other words, in Mr. Fletcher's case at least, the body machinery was kept in perfect fitness without the consumption of any such quantities of fuel as has generally been considered necessary.

Just here it may be instructive to observe that the food consumed by Mr. Fletcher during this seven days' period—and which has been shown to be entirely adequate for his bodily needs during strenuous activity—cost eleven cents daily, thus making the total cost for the seven days seventy-seven cents! If we contrast this figure with the amounts generally paid for average nourishment for a like period of time, there is certainly food for serious thought. Mr. Fletcher avers that he has followed his present plan of living for nearly five years; he usually takes two meals a day; has been led to a strong liking for

sugar and carbohydrates in general and away from a meat diet; is always in perfect health, and is constantly in a condition of fitness for work. He practises thorough mastication, with more complete insalivation of the food (liquid as well as solid) than is usual, thereby insuring more complete and ready digestion and a more thorough utilization of the nutritive portions of the food.

In view of these results, are we not justified in asking ourselves whether we have yet attained a clear comprehension of the real requirements of the body in the matter of daily nutriment? Whether we fully comprehend the best and most economical method of maintaining the body in a state of physiological fitness? The case of Mr. Fletcher just described; the results noted in connection with certain Asiatic peoples; the fruitarians and *nut*arians in our own country recently studied by Professor Jaffa, of the University of California; all suggest the possibility of much greater physiological economy than we as a race are wont to practise. If these are merely exceptional cases, we need to know it, but if, on the other hand, it is possible for mankind in general to maintain proper nutritive conditions on dietary standards far below those now accepted as necessary, it is time for us to ascertain that fact. For, if our standards are now unnecessarily high, then surely we are not only practising an uneconomical method of sustaining life, but we are subjecting ourselves to conditions the reverse of physiological, and which must of necessity be inimical to our well being. The possibility of more scientific knowledge of the natural requirements of a healthy nutrition is made brighter by the fact that the economic results noted in connection with our metabolism examination of Mr. Fletcher is confirmatory of similar results obtained under the direction and scrutiny of Sir Michael Foster at the University of Cambridge, England, during the autumn and winter of last year; and by Dr. Ernest Van Someren, Mr. Fletcher's *collaborateur,* in Venice, on subjects of various ages and of both sexes, some account of which has already been presented to the British Medical Association and to the International Congress of Physiologists at its last meeting at Turin, Italy. At the same time emphasis must be laid upon the fact that no definite and positive conclusions can be arrived at except as the result of careful experiments and observations on many individuals covering long periods of time. This, however, the writer hopes to do in the very near future, with the cooperation of a corps of interested observers.

The problem is far-reaching. It involves not alone the individual, but society as a whole, for beyond the individual lies the broader field of the community, and what proves helpful for the one will eventually react for the betterment of society and for the improvement of mankind in general.

THE FIELD OF MUNICIPAL HYGIENE.

By Professor EDWIN O. JORDAN,
UNIVERSITY OF CHICAGO.

THE modern disposition to revel in the general situation is met by those persons who are disinclined to take a consistently optimistic view of life with several sobering reflections. In regard to that conspicuous phenomenon of modern life, for example, the growth of large cities, attention has frequently been directed to the evil possibilities for the future of the race that are enwombed in city growth. Steady deterioration of mind and body, a tendency to movements of social unrest and disorder, increasingly unsanitary conditions of life are some of the elements in a widely-held belief that the massing or 'herding' of human beings in centers of population is a deplorable and distressing accompaniment of civilization.

It is often forgotten, however, both by those who lament the existence of great cities and by those who count with pride their tale of corn and oil and wine that in the last analysis not only the hope and salvation of the large city, but its growth and very existence depend upon the proper application of methods of municipal hygiene. We need hardly be reminded that many of the factors that make for a concentration of population have been operative in the past with quite as much force as they are to-day. The steady drift from the farm to the town is by no means a modern movement. In the course of the last three hundred years social philosophers have often had occasion to deplore the existence of a migration cityward and the so-called depopulation of the rural districts. In some countries, as in France in the eighteenth century, the chief danger in this movement was thought to lie in its evil effect upon the rural districts, and restrictive measures were advocated for the purpose of keeping a sufficient supply of labor upon the farms. In England the same current toward the cities was noticed, but different forebodings were aroused; the apprehension was expressed that the cities themselves might become unwieldy. Both Elizabeth and James I. issued proclamations forbidding migration into London because of the portentous dimensions that metropolis was thought to be assuming. In spite of the influx of immigrants, however, the actual growth of the large cities was slow if judged by modern standards. In the case of London there is reason to believe that the natural migration into the city was relatively greater two hundred and fifty years ago than it is to-day, and yet at that time its rate of increase was sluggish compared with the swift expansion of its population in the nineteenth century.

There can be no doubt that one reason why cities did not grow so rapidly in the seventeenth and eighteenth centuries as in the nineteenth is the excessively high death rate that prevailed during the earlier period. The flood of immigration, mighty as it was, did little more than make good the places of those citizens who fell victims to grievous sanitary conditions. From the facts that can be obtained it seems to have been universally true that almost up to the beginning of the nineteenth century the death rate of large cities exceeded the birth rate. This was not because the birth rate was abnormally low, but because the death rate was abnormally high. In the medieval city both birth rate and death rate were far higher than at present. Infant mortality must have mounted to a gruesome height. The uncleanliness and overcrowding of city dwellers, now largely relegated to the slums of our great cities, was the normal state of nearly all classes of society in the London and Paris of Louis and Elizabeth. Mr. Frederick Harrison has condensed into his own vigorous language the annals of many of the historians of the middle ages.

> The old Greek and Roman religion of external cleanness was turned into a sin. The outward and visible sign of sanctity now was to be unclean. No one was clean, but the devout Christian was unutterably foul. The tone of the Middle Ages in the matter of dirt was a form of mental disease. Cooped up in castles and walled cities, with narrow courts and sunless alleys, they would pass day and night in the same clothes, within the same airless, gloomy, windowless, and pestiferous chambers; they would go to bed without night clothes, and sleep under uncleansed sheepskins and frieze rugs; they would wear the same leather, fur and woolen garments for a lifetime, and even for successive generations; they ate their meals without forks, and covered up the orts with rushes; they flung their refuse out of the window into the street or piled it up in the back-yard; the streets were narrow, unpaved, crooked lanes through which, under the very palace turrets, men and beasts tramped knee-deep in noisome mire. This was at intervals varied with fetid rivulets and open cesspools; every church was crammed with rotting corpses and surrounded with graveyards, sodden with cadaveric liquids, and strewn with disinterred bones. Round these charnel houses and pestiferous churches were piled old decaying wooden houses, their sole air being these deadly exhalations, and their sole water supply being these polluted streams or wells dug in this reeking soil. Even in the palaces and castles of the rich the same bestial habits prevailed. Prisoners rotted in noisome dungeons under the banqueting hall; corpses were buried under the floor of the private chapel; scores of soldiers and attendants slept in gangs for months together in the same hall or guard-room where they ate and drank, played and fought.

The unsanitary conditions thus relentlessly portrayed must have had the same effect upon the health of all town inhabitants that similar conditions now exert upon the denizens of the 'crowded' and 'poor' wards of our modern cities.

So long as the city death rate exceeded the birth rate, the cities, in spite of the ceaseless thronging in of immigrants, could not grow as they have grown since. The economic equilibrium between town and country probably did not permit of any more considerable transfer of

population than actually occurred, and this transfer merely sufficed to keep the city population at a fairly constant level. As soon, however, as the city death rate began to decline and even to fall below the birth rate, the city population increased with leaps and bounds. This change is comparatively modern. London did not show a natural increase, due to excess of births, until the beginning of the nineteenth century, and Berlin did not reach this point until 1810.*

	Excess of Births.		Net	Total
	Number.	Percentage.	Immigration.	Increase.
1711–1815	—31,310	—0.2	1.4	1.2
1816–1837	23,505	0.5	1.3	1.8
1838–1858	55,513	0.7	1.6	2.3
1858–1875	95,460	0.8	3.2	4.0
1875–1895	189,240	1.1	1.6	2.7

It must not be forgotten, moreover, that simple excess of birth rate is not a fair measure of the decline that has occurred in the death rate. The birth rate itself has not remained constant, but in the last thirty years has materially diminished in nearly all civilized lands, so that in reality the decline in death rate is far greater than can be indicated by mere change in the absolute or proportional excess of births.

If the large cities have lost some of their former evil repute in the matter of healthfulness, the improvement must plainly be attributed to the development of the art of municipal hygiene. The dangers to health resulting from the massing of human beings within comparatively narrow limits are now fairly well known, but such knowledge has not always been available and is even now not always acted upon. The question of water supply affords a pregnant illustration. That some connection existed between outbreaks of disease and the character of drinking water was seen darkly all through the middle ages, but the groping speculations on the subject only led to the hypothesis, fraught with terrible consequences to an unhappy people, that 'the Jews had poisoned the wells.' It was not until about the middle of the last century (1854) that an explosion of cholera in London among the users of water from the 'Broad Street Pump' established definitely in the minds of physicians the truth that the specific poison of Asiatic cholera could be conveyed by means of infected drinking water. Some years later a similar conviction was reached regarding typhoid fever.

The medieval ignorance concerning the direct infectivity of drinking water and its importance as a factor in the spread of disease told heavily against the cities. In sparsely populated districts the likelihood that any particular well or spring would become infected was comparatively slight, and even if a single well did become accidentally polluted neighboring wells or springs used by other families might still

* A table is given by Kuczynski which shows the relative shares of immigration and excess of birth rate in producing the growth of Berlin.

remain entirely wholesome and incapable of spreading disease. The radius of infection was likely to be very circumscribed. In cities, on the other hand, where the persons resorting to a particular well might be very numerous,* the contamination of a single source could lead to disease and death, not merely in one or two families but in scores of families. Again, the greater liability to contamination to which a well in a densely settled region was exposed was an added menace and enhanced the peril to the city dweller from this source. The introduction of general public water supplies lessened to a considerable extent the latter evil and placed the city resident in a more advantageous position. The public water supply of large towns became on the whole purer than the water formerly obtainable by the private citizen, and since the supply was often brought from some distance, it was not liable to increased pollution as a direct consequence of the increase in the density of the city population. But on the other hand, the introduction of the public supply increased the danger from diffusion. Far greater numbers of people were affected. If the public supply became infected with a specific disease germ, the germ was distributed among much wider circles, and the infection became a momentous matter to the whole community. This in turn had the natural result that the attention formerly directed by the more intelligent members of the community to the care of their own private water supplies was now turned towards the public supply, and the problems of expert selection, supervision and control of the public supply began to receive the attention they deserved. There remained in many municipalities, however, so much inertia that this obvious duty was neglected or abandoned to the tender mercies of greedy politicians.

The conditions in many parts of the United States at the present day testify eloquently to the existence of this transition stage. In those sections, however, where it is the rule for proper care to be taken of the public water supplies the city death rate from typhoid fever is low, often lower in fact than in the surrounding country districts. In the year 1900, for instance, the typhoid fever death rate in the thickly populated 'Maritime District' of New York State, comprising chiefly the territory of Greater New York, with a population density of 1,535 per square mile, was only 2.0 per 10,000 inhabitants, while in the sparsely settled 'Adirondacks and Northern' district, with a population per square mile of 26, the reported death rate from typhoid fever was almost twice as great (3.9).

Theoretically, at least, the city ought to possess a decided advantage over the country in the matter of water supply. It ought to be possible for a large city to place its public supply under expert and specialized control, thus averting from the ignorant and careless members of

* At least 137 persons were known to have drunk water from the Broad Street pump shortly before the outbreak of cholera in 1854.

the community the consequences that would otherwise follow their ignorance and neglect. In other words, the quality of a public water supply ought easily to be better than the average water supply that would be obtained by the average citizen for himself under rural conditions. If the real situation is sometimes otherwise it is not because impure water is one of the necessary and inevitable accompaniments of city life, but because the city has failed to avail itself of the superior resources at its disposal.

The matter of water supply is not the only respect in which the city should possess a practical advantage. The opportunities for speedy and efficient treatment of many acute diseases are greater in a large and compact community than in one sparsely settled. Well-equipped hospitals and dispensaries, the most expert surgeons, the best trained nurses are all most likely to be found in the centers of population. Many city families have experienced the increased anxiety and danger that accompany a case of serious illness occurring when the family is away for the summer in a little country town. The careful nursing and the timely and expert treatment which even those in moderate circumstances can command in a large city are quite out of the reach of the majority of rural dwellers.

In addition to the advantages that accrue to the city dweller from opportunities for a particularly efficient treatment of disease in general, there are certain specific instances where early diagnosis and prompt treatment of a particular malady may suffice to turn the scale in favor of the patient. A notable example is presented in the case of diphtheria. All the larger cities and most of the smaller ones have in recent years provided themselves with well-equipped municipal laboratories in which microscopical and cultural examinations are freely made at the request of any physician. By the utilization in this way of the best modern appliances and methods and of experienced and specially qualified service, it is possible in the majority of cases for the physician to discover within twenty-four hours whether his patient is infected with the virulent diphtheria bacillus or is merely suffering from an ordinary and only remotely dangerous sore throat. The importance of an early diagnosis in the case of diphtheria is supreme for the reason that the administration of the diphtheria antitoxin is most likely to prove successful in the early stages of the disease. The antitoxin can not repair any damage that may have been done to the tissues of the body, but can only neutralize and render harmless the diphtheritic poison that is circulating in the blood. If the presence of a true diphtheritic infection is not recognized until late in the course of the disease the injection of the antitoxin may have little influence upon the outcome, since the heart and other organs may have suffered irreparable injury before the nature of the disease becomes understood. It is of the utmost importance, therefore, for the physician to

recognize the existence of diphtheria and to be in a position to employ without delay the specific remedy. In this respect the city physician is at a distinct advantage in treating diphtheria as compared with his brother in the country districts, although the latter may be often his equal, perhaps his superior in individual ability. Both as regards the early diagnosis of diphtheria and the speedy procuring of reliable antitoxin the city practitioner occupies a position of vantage. Whether the city physician always avails himself of his superior opportunities is another matter. The opportunities certainly exist, and with the development sure to take place in the efficiency of municipal laboratories, the perfection of telephone and messenger service and the establishment of stations for the delivery of antitoxin, the balance is likely to turn even more in his favor. Individual ability and special training in the use of the microscope will sometimes enable a country physician to obtain the necessary information for himself, but in accordance with the laws of specialization, such tasks in the larger towns will devolve more and more upon the expert who devotes his whole time to the work.

The same tendency is at work in other directions. The scope of municipal laboratory work is evidently broadening with the advance of scientific medicine, and new fields of activity are continually opening before it. In the diagnosis of malarial fever and typhoid fever and in the early recognition of consumption it is already rendering valuable aid to the busy city practitioner. The actual degree of usefulness of the municipal laboratory to the community is still made the shuttlecock of local political conditions, but this stage can last only so long as the city dweller continues to close his eyes to the part that might be played by the laboratory in securing and safeguarding the public health.

There are at least two particulars in which the city is still at a conspicuous disadvantage as compared with the country. These are, first, the high infant mortality, and second, the greater prevalence of various infectious diseases.

As regards the first of these, it is well known that there is a clearly established relation between infant mortality and city milk supply. The richness of milk in those very substances that render it valuable as a food is a source of danger. Not only children but microbes find milk an exceptionally nutritious food. It is not surprising that milk that is at the start carelessly collected and carelessly handled and then carried a long distance should often swarm with countless microörganisms by the time it is delivered to the consumer. In hot weather the growth of bacteria in milk is especially rapid, and much of the milk that is distributed in cities during the summer season is far advanced in the process of decomposition. The high death rate among bottle-fed infants during the summer months, and the traditional popular dread of the 'second summer' as a critical period in infant development are directly traceable to the use of stale milk. The evil is by no means

irremediable. Many enterprising milk dealers have already demonstrated the enormous improvement that can be brought about in the quality of milk by attention to simple details of collection and transportation. A high authority says of the present New York City milk supply: "There is an inexcusable lack of cleanliness in the methods of procuring milk and of care in sufficiently cooling and keeping it during its transportation. Even in the matter of sending milk to the railroad many farmers take twenty-four hours more than is necessary, keeping back one half of their milk in order to save the trouble and expense of making more than one trip each day to the station." *

In addition to the dangers and disadvantages arising from the entrance into milk of the bacteria of decomposition, there is reason to believe that the germs of disease also sometimes find their way into milk. Outbreaks of specific diseases like diphtheria and typhoid fever have been traced to infection of the milk supply, and evidence is accumulating that cases of disease from this source are more numerous than formerly supposed. There is good ground for believing that the indiscriminate use of raw milk is one of the most serious sanitary indiscretions committed by the average city dweller. The practical difficulties in the way of exercising an adequate supervision and control over the milk supply are often over-estimated by city health authorities. A large amount of time and energy is now devoted to the detection of chemical adulteration and of dilution or 'extension' of the milk, but little or nothing is attempted in regard to the vastly more important matter of protecting the general character of the supply. Much good might be accomplished by the systematic official cooperation of the health authorities with the various associations of milk dealers who are in a position to apply effective pressure to slovenly or wilfully careless producers. The milk dealers and producers as a class are rapidly awakening to the importance of scientific method, and will respond readily to any attempt made to bring the results of scientific investigation to bear upon their work. In individual instances that have come to the writer's notice, milk dealers, in their eagerness to do the right thing, are actually committing grave sanitary mistakes, and their customers receive no benefit from the dealers' endeavors, because the dealers themselves are not properly guided. Certainly the municipal authorities in some places are not performing their whole duty in this regard.

The greater general prevalence of infectious diseases among city dwellers as compared with the rural population is a second important respect in which present city conditions are strikingly disadvantageous. The more abundant opportunities for infection that are afforded, indeed made necessary, by the nature of city life and occupation can not be easily avoided, but at least their exact character can be made known

* W. H. Park, *Journal of Hygiene*, July, 1901.

and the grosser possibilities in some measure controlled. The enforcement of greater cleanliness in public buildings and conveyances, a better system for the notification and control of cases of infectious disease—a matter in which American municipalities are notoriously lax—provision of adequate hospital facilities for the reception and care of patients suffering from infectious disease are among the measures which would unquestionably reduce the city death rate from the infectious diseases. Above all, a thoroughgoing system of medical inspection of schools should be introduced. Nearly all the infectious diseases are most prevalent and most fatal among children of school age, and it would seem as if this were a highly important field in which the energies of municipal health authorities should be exercised. In some cities, as in Boston and Chicago, school inspection has been introduced with successful results, but lack of funds for the purpose has prevented a general and thorough adoption of the system. It would seem as if no reasonable expenditure should be allowed to stand in the way of this important public health measure. If money is available for safeguarding the public health in any way, it ought to be available for this purpose. If necessary, the school year should be shortened to secure the funds needed. The saving to the community of the expense of caring for cases of even the minor and less dangerous infectious diseases should constitute an effective financial argument for the general adoption of school inspection. It is perhaps significant that the growing unwillingness on the part of many of the most intelligent and public-spirited members of the community to send their children to the public schools is based on the great liability of the children to contract infections under existing conditions. The removal of this grave drawback to the public school system would in itself seem an object worth striving after.

If a small fraction of the money now expended under compulsion for over-elaborate and unnecessarily complex systems of plumbing were devoted to measures better calculated to prevent the spread of contagion, the city death rate from infectious diseases would be materially lessened and would not so largely exceed the country death rate from the same causes, as is at present the case. The campaign against infectious disease in cities should not be conducted with antiquated methods and along lines not countenanced by recent investigation, but should take advantage of the most recent scientific discoveries and above all should be carried on with a full understanding of the nature and degree of success that may reasonably be expected from the methods it is applying.

Municipal hygiene, then, to be worthy of the name should not confine itself to combating only the most dreaded or most dramatic forms of disease, but after a scientific study of the whole problem of city life should enter upon a carefully planned and systematic endeavor to re-

move or lessen some of the causes of excessive disease. There does not seem to be any sign that the desire of modern man to build himself cities and to live in them is weakening. So far ahead as any one can see, cities will continue to crowd to the edge of the stream of human life in 'a blacker, incessanter line.' Unknown forces will doubtless arise in the future which will ameliorate the conditions of city life in the way that the trolley has already done, but there will always exist certain problems peculiarly urban and created by what some curiously term the artificial conditions of city life. It should be the task of a well-conceived, far-seeing art of municipal hygiene to deal with the sanitary aspect of these problems. It does not by any means follow because some of the conditions of city life at present are distinctly inimical to human welfare that they should always remain so. And it should be recognized, furthermore, that the city possesses, within and because of its own structure, certain hygienic advantages, of which to be sure it does not always avail itself, but which in the long run will count heavily in its favor. There are already indications that these factors are becoming operative. The approximation of the urban to the rural death rate shown by the last census to have occurred in several states is not in all probability to be accounted for by a sudden shifting of the age and sex distribution of the population, but marks a real improvement in the sanitary conditions surrounding city life.

Excess of Urban Over Rural Death Rate.

Registration State.	1890.	1900.
Connecticut	3.9	.1
Massachusetts	2.7	.8
New Hampshire	1.0	1.3
New Jersey	7.9	3.3
New York	9.3	4.0
Rhode Island	1.1	.4
Vermont	3.0	.7

Since it is not true that urban life necessarily and inherently entails a higher death rate than rural life, it would seem time to dismiss the gloomy forebodings sometimes expressed that the cities are destined to become 'the graveyard of the human race,' that an inevitable physical degeneration is bound to attend life in the great centers of population, and that density of population is in itself a deplorable accompaniment of modern industrial development. Rather do the signs point to an increasing consciousness on the part of the city dweller of the hygienic advantages bestowed upon him by his position, to a deliberate and intelligent attempt on his part to master the forces that make for the excessive prevalence of disease in crowded centers, and especially to a growing realization of the necessity for a careful study and appreciation of the hygienic possibilities of his environment.

UNIVERSITY TENDENCIES IN AMERICA.*

By President DAVID STARR JORDAN,

LELAND STANFORD JUNIOR UNIVERSITY.

THE business of the university is to train men to know, to think and to do. To be will take care of itself, if the others are provided for. Wisdom is knowing what one ought to do next. Skill is knowing how to do it. Virtue is doing it. Religion is the working theory of life. It deals with the reasons why one ought to do. To all these ends the university is devoted. It does not make men. It remodels them to bring the powers they have to greater effectiveness. It brings, according to Emerson, 'every ray of varied genius to its hospitable halls,' that by their united influence 'they may strike the hearth of the youth in flame.'

Most precious of all possessions of the state is the talent of its citizens. This exists not in fact, but in possibility. What heredity carries over is not achievement, but tendency, a mode of direction of force which makes achievement possible. But to bring about results training is necessary. There can never be too many educated men, if by education we mean training along the lines of possible individual success. With birth, Emerson tells us, 'the gate of gifts is closed.' We can no longer secure something for nothing. The child's character is a mosaic of unrelated fragments, bits of heredity from a hundred sources. It is the work of education to form these into a picture. It is the art of living to range these fragments to form a consistent and effective personality.

It is the duty of the university among other things to take hold of these fragments of human possibilities and to arrange them so as to fit them for achievement. It is another duty 'to bring men to their inheritance.' This inheritance consists of the gathered experience of the past, that truth which is won through contact with realities, and with this the knowledge of the methods by which men have tested truth. Again the university has the public duty of preparing the instruments of social need.

The kings have recognized the need of universities and university men. In this need Alfred founded Oxford and Charlemagne the University of Paris. The Emperor William is quoted as saying that

* Abstract of an address before the North Central Association of Colleges and High Schools, Chicago, April 3, 1903.

'Bismarck and von Moltke were but tools in the hands of my august grandfather.' To furnish more such tools and in all the range of human activity, the University of Berlin was established.

In like manner the great historical churches and their lesser branches have founded universities each in its degree, because of the church's need of men. It has demanded trustworthy agents, expert dialecticians, great persuaders and spiritual leaders, and these have arisen in the church universities in obedience to the demand.

A like need of leaders is felt in democracy. It has a work to do greater than that of king or church and this work must be done by skilful and loyal hands. Democracy means opportunity. The greatest discovery of this most democratic twentieth century will be that 'the straight line is the shortest distance between two points.' This is a geometric definition of democracy. It trusts not to Lord this and the Earl of that. Its leaders are not chosen arbitrarily as the earliest offshoot from each link in the strain of heredity. When democracy has a man's work to do, it calls on the man who can do it. Such men it creates, and wherever they spring up they are developed in the sunshine of popular education. Democracy does not mean equality, a dead level of possession, happiness or achievement. It means equality before the law, that is the abolition of artificial distinctions made in the dark ages. It means equality of start, never equality of finish, and the most absolute equality of start makes the final equality the greater. As democracies need universities, so do universities need democracy as a means of recall to duty. Lincoln used to say that 'bath of the people' was necessary now and then for public men. This 'bath of the people' the university needs lest it substitute pedantry for wisdom, or lest it become a place for basking instead of an agency for training.

An Oxford man said not long since: 'Our men are not scholars; our scholars are not men.' Those we call scholars are bloodless pedants, finical and ineffective. Those we call men, strong, forceful, joyous, British boys, have no adequate mental training. Whether this be true of Oxford, it is often true in all universities. It is the sign that there is something wrong in practise or ideals. Scholarship should be life, and life should be guided by wisdom. The university should be a source of power, not an instrument in social advancement. Its degree should be not a badge of having done the proper thing, a device to secure the 'well-dressed feeling,' given also by 'Boston garters' and by faultless ties. The college degree is an incident in scholarship, a childish toy, so far as the real function of building up men is concerned. Prizes, honors, badges and degrees—all these matters have no necessary place in the machinery of higher education. If our universities had grown up in response to the needs of the people,

not in imitation of the colleges of England, we should never have been vexed by these things, and never have felt any need of them.

The primitive American college was built strictly on English models. Its purpose was to breed clergymen and gentlemen, and to fix on these its badge of personal culture, raising them above the common mass of men. Till within the last thirty years the traditions of the English tripos held undisputed sway. We need not go into details of the long years in which Latin, Greek and mathematics with a dash of outworn philosophy constituted higher education in America. The value of the classical course lay largely in its continuity. Whoever learned Greek, the perfect language and the noble literature, gained something with which he would never willingly part. Even the weariness of Latin grammar and the intricacies of half-understood calculus have their value in the comradery of common suffering and common hope. The weakness of the classical course lay in its lack of relation to life. It had more charms for pedants than for men, and the men of science and the men of action turned away hungry from it.

The growth of the American university came on by degrees, different steps, some broadening, some weakening, by which the tyranny of the tripos was broken, and the democracy of studies established with the democracy of men.

It was something over thirty years ago when Herbert Spencer asked this great question: 'What knowledge is of most worth?' To the schoolmen of England this came as a great shock, as it had never occurred to most of them that any knowledge had any value at all. Its function was to produce culture, which, in turn, gave social position. That there were positive values and relative values was new in their philosophy. Spencer went on to show that those subjects had most value which most strengthened and enriched life, first, those needful to the person, then those of value in professional training, then in the rearing of the family, the duty as a citizen, and finally those fitting for esthetic enjoyment. For all these, except the last, the English universities made no preparation, and for all these purposes Spencer found the highest values in science, the accumulated, tested, arranged results of human experience. Spencer's essay assumed that there was some one best course of study—the best for every man. This is one of the greatest fallacies in education. Moreover, he took little account of the teacher, perhaps assuming with some other English writers that all teachers were equally inefficient, and that the difference between one and another may be regarded as negligible.

It has been left for American experimenters in education to insist on the democracy of the intellect. The best subjects for any man to study are those best fitted for his own individual development,

those which will help make the actual most of him and his life. Democracy of intellect does not mean equality of brains, still less indifference in regard to their quality. It means simply fair play in the schedule of studies. It means the development of fit courses of study, not traditional ones, of a 'tailor-made' curriculum for each man instead of the 'hand-me-down' article, misfitting all alike.

In the time of James II., Richard Rumbold 'never could believe that God had created a few men already booted and spurred, with millions already saddled and bridled for these few to ride.' In like fashion, Andrew Dickson White could never believe that God had created a taste for the niceties of grammar or even the appreciation of noble literature, these few tastes to be met and trained while the vast body of other talents were to be left unaided and untouched, because of their traditional inferiority. In unison with President White, Ezra Cornell declared that he 'would found an institution where any person could find instruction in any study.' In like spirit the Morrill Act was framed, bringing together all rays of various genius, the engineer, and the psychologist, the student of literature and the student of exact science, 'Greek-minded' men and tillers of the soil, each to do his own work in the spirit of equality before the law. Under the same roof each one gains by mutual association. The literary student gains in seriousness and power, the engineer in refinement and appreciation. Like in character is the argument for co-education, a condition encouraged by this same Morrill Act. The men become more refined from association with noble women, the women more earnest from association with serious men. The men are more manly, the women more womanly in co-education, a condition opposed alike to rowdyism and frivolity.

In the same line we must count the influence of Mark Tappan, perhaps the first to conceive of a state university, existing solely for the good of the state, to do the work the state most needs, regardless of what other institutions may do in other states. Agassiz in these same times insisted that advanced work is better than elementary, for its better disciplinary quality. He insisted that Harvard in his day was only 'a respectable high school, where they taught the dregs of education.' Thorough training in some one line he declared was the backbone of education. It was the base line by which the real student was enabled to measure scholarship in others.

In most of our colleges the attempt to widen the course of study by introducing desirable things preceded the discovery that general courses of study prearranged had no real value. We have learned all prescribed work is bad work unless it is prescribed by the nature of the subject. The student in electrical engineering takes to mathematics, because he knows that his future success with electricity de-

pends on his mastery of mechanics and the calculus. In the same fashion, the student in medicine is willing to accept chemistry and physiology as prescribed studies. But a year in chemistry, or two years in higher mathematics, put in for the broadening of the mind or because the faculty decrees it, has no broadening effect. Work arbitrarily prescribed is always poorly done, sets low standards, and works demoralization instead of training. There can not be a greater educational farce than the required year of science in certain literary courses. The student picks out the easiest science, the easiest teacher and the easiest way to avoid work, and the whole requirement is a source of moral evil. Nothing could be farther from the scientific method than a course in science taken without the element of personal choice.

The traditional courses of study were first broken up by the addition of short courses in one thing or another, substitutes for Latin or Greek, patchwork courses without point or continuity. These substitute courses were naturally regarded as inferior, and for them very properly a new degree was devised, the degree of B.S.—Bachelor of Surfaces.

That work which is required in the nature of things is taken seriously. Serious work sets the pace, exalts the teacher, inspires the man. The individual man is important enough to justify his teachers in taking the time and the effort to plan a special course for him.

Through the movement towards the democracy of studies and constructive individualism, a new ideal is being reached in American universities, that of personal effectiveness. The ideal in England has always been that of personal culture; that of France, the achieving, through competitive examinations, of ready-made careers, the satisfaction of what Villari calls 'Impiegomania,' the craze for appointment; that of Germany, thoroughness of knowledge; that of America, the power to deal with men and conditions. Everywhere we find abundant evidence of personal effectiveness of American scholars. Not abstract thought, not life-long investigation of minute data, not separation from men of lower fortune, but the power to bring about results is the characteristic of the American scholar of to-day.

From this point of view the progress of the American university is most satisfactory, and most encouraging. The large tendencies are moving in the right direction. What shall we say of the smaller ones?

Not long ago, the subject of discussion in a thoughtful address was this: the 'Peril of the Small College.' The small college has been the guardian of higher education in the past. It is most helpful in the present and we can not afford to let it die. We understand that the large college becomes the university. Because it is rich, it at-

tempts advanced work and work in many lines. It takes its opportunity, and an opportunity which the small college can not grasp. Advanced work costs money. A wide range of subjects, taught with men, libraries and laboratories, is a costly matter, but by a variety of supply the demand is formed. The large college has many students, because it offers many opportunities. Because large opportunities bring influence and students and gifts, there is a tendency to exaggerate them. We are all prone to pretend that the facilities we offer are greater than is really the case. We are led to shout, because people are indifferent to us.

The peril of the small college is the peril of all colleges, the temptation of advertising. All boasting is self-cheapening. The peril of the small college is that in its effort to become large it shall cease to be sound. The small college can do good elementary work in several lines. It can do good advanced work in a very few. If it keeps its perspective, if it does only what it can do well, and does not pretend that bad work is good work, or that the work beyond its reach is not worth doing, it is in no danger. The small college may become either a junior college or high-grade preparatory school, sending its men elsewhere for the flower of their college education, or else it must become a small university running narrowly on a few lines, but attending to these with devotion and persistence. Either of these are honorable conditions. For the first of these the small college has a great advantage. It can come close to its students; it can 'know its men by name.' The value of a teacher decreases with the square of his distance from the pupil. The work of the freshman and sophomore years in many of our great colleges is sadly inadequate, because its means are not fitted to its ends. In very few of our large colleges does the elementary work receive the care its importance deserves.

The great college can draw the best teachers away from the small colleges. In this regard the great college has an immense advantage. It has the best teachers, the best trained, the best fitted for the work of training. But in most cases the freshman never discovers this. There is no worse teaching done under the sun than in the lower classes of some of our most famous colleges. Cheap tutors, unpractised and unpaid boys are set to lecture to classes far beyond their power to interest. We are saving our money for original research, careless of the fact that we fail to give the elementary training which makes research possible. Too often, indeed, research itself, the noblest of all university functions, is made an advertising fad. The demands of the university press have swollen the literature of science, but they have proved a doubtful aid to its quality. Get something ready. Send it out. Show that we are doing something. All this never advanced

science. It is through men born to research, trained to research, choicest product of nature and art, that science advances.

Another effect of the advertising spirit is the cheapening of salaries. The smaller the salaries, the more departments we can support. It is the spirit of advertising that leads some institutions to tolerate a type of athlete who comes as a student with none of the student's purpose. I am a firm believer in college athletics. I have done my part in them in college and out. I know that 'the color of life is red,' but the value of athletic games is lost when outside gladiators are hired to play them. No matter what the inducement, the athletic contest has no value except as the spontaneous effort of the college man. To coddle the athlete is to render him a professional. If an institution makes one rule for the ordinary student and another for the athlete it is party to a fraud. Without some such concession, half the great football teams of to-day could not exist. I would rather see football disappear and the athletic fields closed for ten years for fumigation than to see our colleges helpless in the hands of athletic professionalism, as many of them are to-day.

This is a minor matter in one sense, but it is pregnant with large dangers. Whatever the scholar does should be clean. What has the support of boards of scholars should be noble, helpful and inspiring. For the evils of college athletics, the apathy of college faculties is solely responsible. The blame falls on us: let us rise to our duty.

There is something wrong in our educational practise when a wealthy idler is allowed to take the name of student, on the sole condition that he and his grooms shall pass occasional examinations. There is no justification for the granting of degrees on cheap terms, to be used in social decoration. It is said that the chief of the great coaching trust in one of our universities earns a salary greater than was ever paid to any honest teacher. His function is to take the man who has spent the term in idleness or dissipation, and by a few hours' ingenious coaching to enable him to write a paper as good as that of a real student. The examinations thus passed are mere shams, and by the tolerance of the system the teaching force becomes responsible for it. No educational reform of the day is more important than the revival of honesty in regard to credits and examinations, such a revival of honest methods as shall make coaching trusts impossible.

The same methods which cure the aristocratic ills of idleness and cynicism are equally effective in the democratic vice of rowdyism. With high standards of work, set not at long intervals, by formal examinations, but by the daily vigilance and devotion of real teachers, all these classes of mock students disappear.

The football tramp vanishes before the work-test. The wealthy

boy takes his proper place when honest, democratic brain effort is required of him. If he is not a student, he will no longer pretend to be one and ought not to be in college. The rowdy, the mucker, the hair-cutting, gate-lifting, cane-rushing imbecile is never a real student. He is a gamin masquerading in cap and gown. The requirement of scholarship brings him to terms. If we insist that our colleges shall not pretend to educate those who can not or will not be educated, we shall have no trouble with the moral training of the students.

Above all, in the West, where education is free, we should insist that free tuition means serious work, that education means opportunity, that the student should do his part, and that the degree of the university should not be the seal of academic approbation of four years of idleness, rowdyism, profligacy or dissipation.

Higher education, properly speaking, begins when a young man goes away from home to school. The best part of higher education is the development of the instincts of the gentleman and the horizon of the scholar. To this end, self-directed industry is one of the most effective agents. As the force of example is potent in education, a college should tolerate idleness and vice neither among its students nor among its teachers.

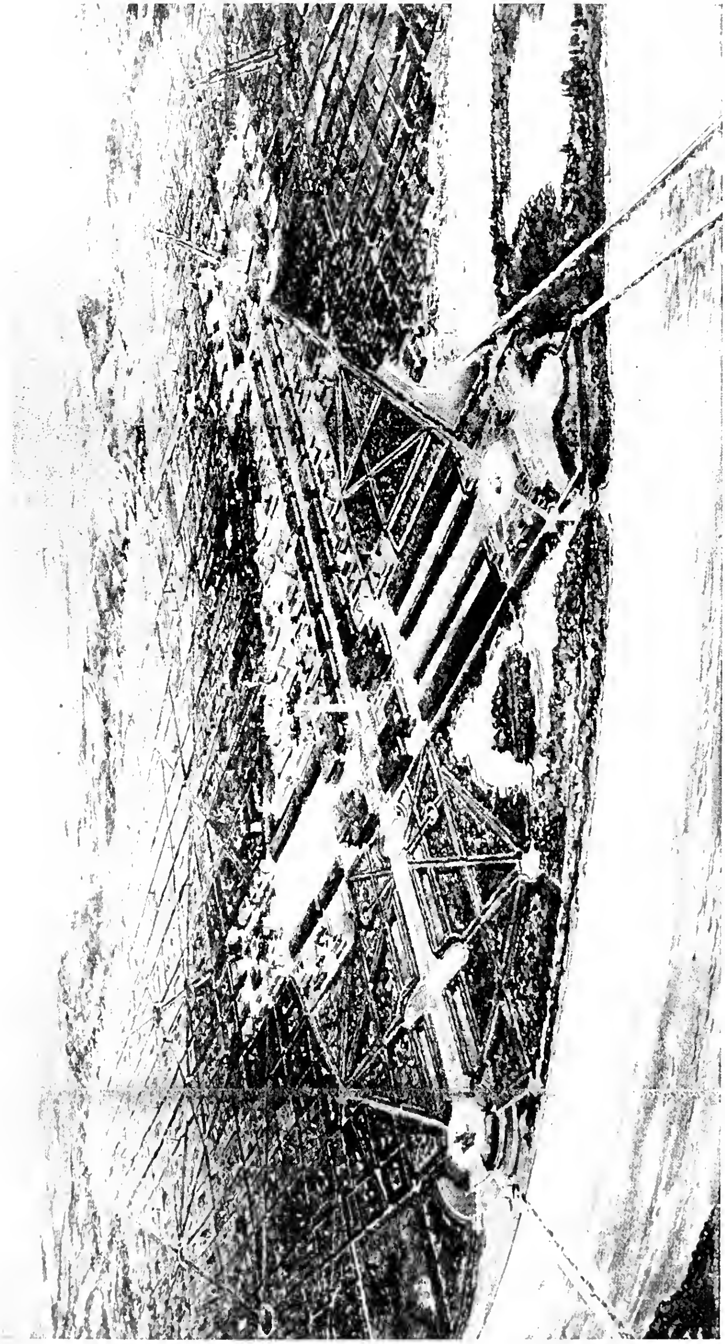
THE IMPROVEMENT OF THE CITY OF WASHINGTON.*

THE city of Washington differs from all other American cities in the fact that in its original plan parks were laid out as settings for public buildings. Even its broad avenues were arranged so as to enhance the effect of the great edifices of the nation; and the squares at the intersection of the wide thoroughfares were set apart as sites for memorials to be erected by the various states. Park, in the modern sense of a large public recreation ground, there was none; but small areas designed to beautify the connections between the various departments of government were numerous.

During the nineteenth century, however, the development of urban life and the expansion of cities has brought into prominence the need, not recognized a hundred years ago, for large parks to preserve artificially in our cities passages of rural or sylvan scenery and for spaces adapted to various special forms of recreation. Moreover, during the century that has elapsed since the foundation of the city the great space known as the Mall, which was intended to form a unified connection between the Capitol and the White House, and to furnish sites for a certain class of public buildings, has been diverted from its original purpose and cut into fragments, each portion receiving a separate and individual informal treatment, thus invading what was a single composition. Again, many reservations have passed from public into private ownership, with the result that public buildings have lost their appropriate surroundings, and new structures have been built without that landscape setting which the founders of the city relied on to give them beauty and dignity.

Happily, however, little has been lost that can not be regained at reasonable cost. Fortunately, also, during the years that have passed the Capitol has been enlarged and ennobled, and the Washington Monument, wonderful alike as an engineering feat and a work of art, has been constructed on a site that may be brought into relations with the Capitol and the White House. Doubly fortunate, moreover, is the fact that the vast and successful work of the engineers in redeeming the Potomac banks from unhealthy conditions gives opportunity for enlarging the scope of the earlier plans in a manner corresponding to

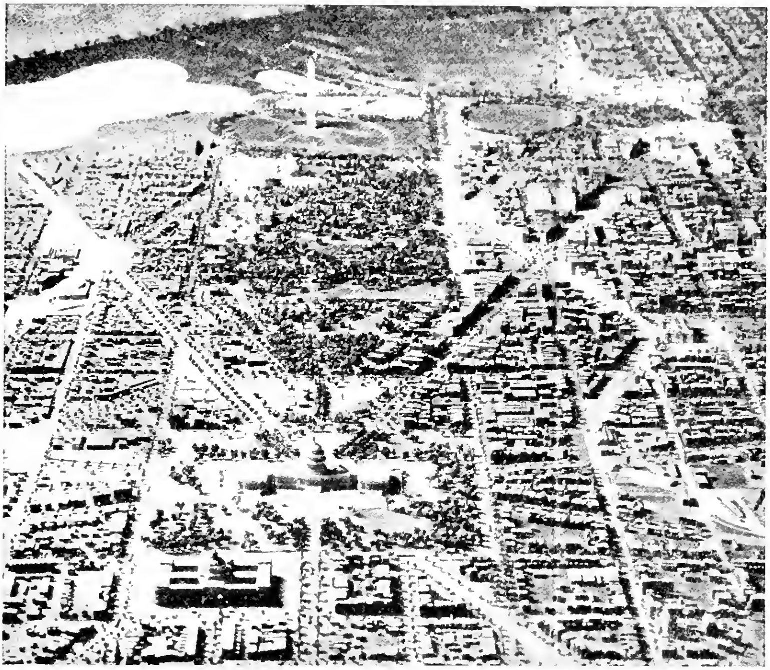
* From the report to the Senate committee on the District of Columbia of the Park Commission, consisting of Daniel H. Burnham, Chicago; Augustus St. Gaudens, New York; Charles F. McKim, New York, and Frederick Law Olmsted, Jr., Brookline.



Bird's-Eye View of General Plan, from point taken 4,000 feet above Arlington.

the growth of the country. At the same time the development of Potomac Park both provides for a connection between the parks on the west and those on the east, and also it may readily furnish sites for those memorials which history has shown to be worthy a place in vital relation to the great buildings and monuments erected under the personal supervision of the founders of the republic.

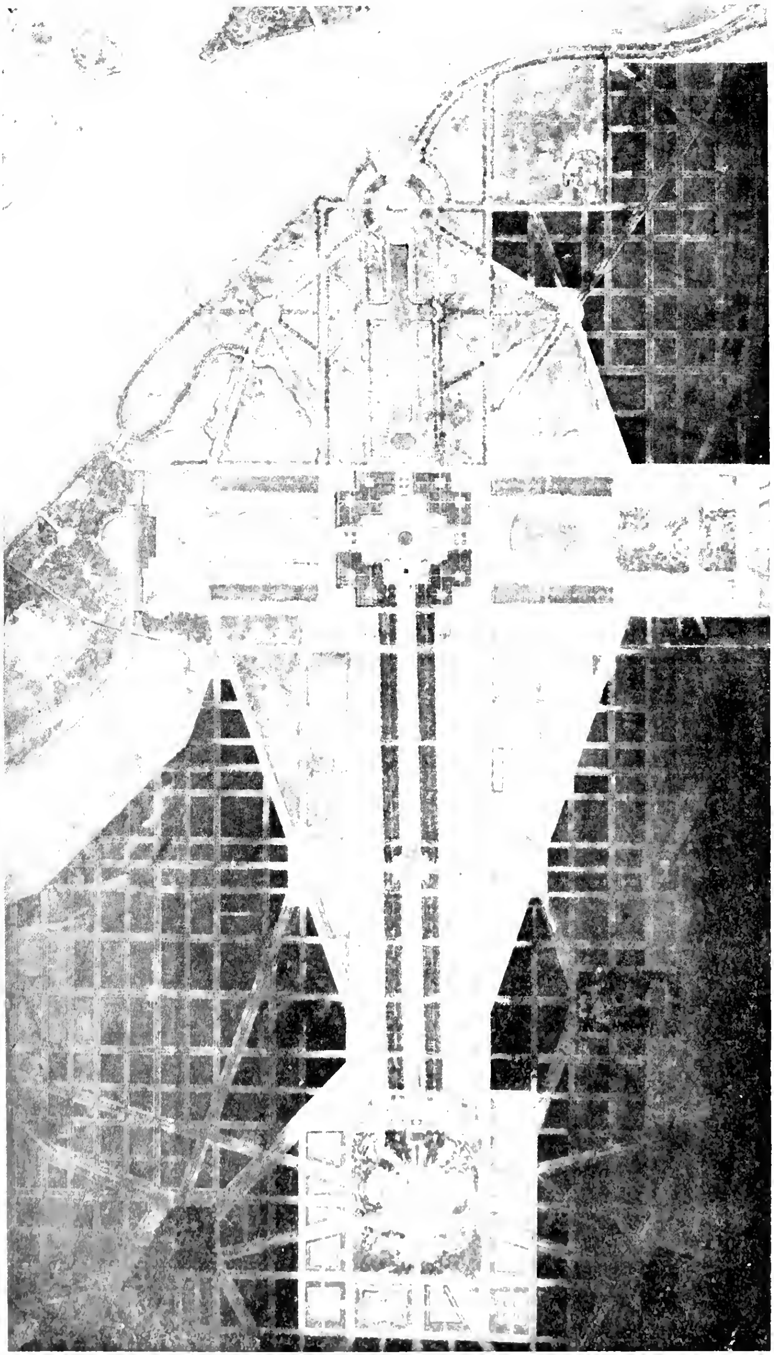
Now that the demand for new public buildings and memorials has reached an acute stage, there has been hesitation and embarrassment in locating them because of the uncertainty in securing appropriate sites. The commission was thus brought face to face with the problem of



Model of the Mall, showing Present Conditions. Looking west.

devising such a plan as shall tend to restore that unity of design which was the fundamental conception of those who first laid out the city as a national capital, and of formulating definite principles for the placing of those future structures which, in order to become effective, demand both a landscape setting and a visible orderly relation one to another for their mutual support and enhancement.

To the unique problem of devising a way of return to the original plan of the city of Washington, was added the task of suggesting lines for the development of those large parks which have been obtained in recent years either by purchase or by reclamation; of advising the



General Plan of the Mall System.

acquisition of such additional spaces as are deemed necessary to create a modern park system; and of selecting for purchase and improvement suitable connections between the various park areas.

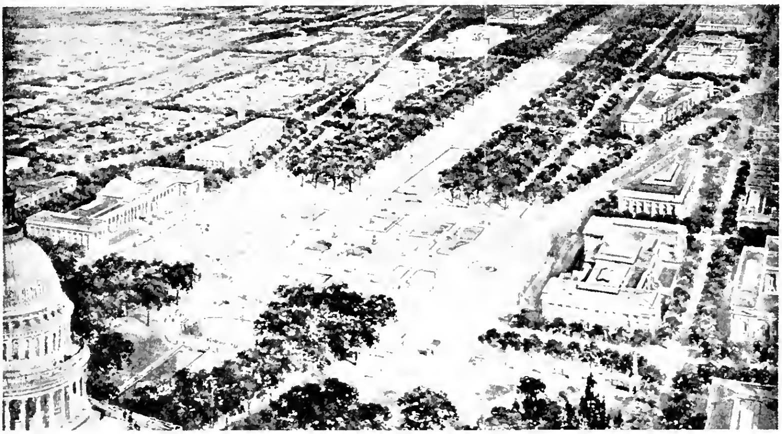
If Washington were not a nation's capital, in which the location of public buildings is of the first importance, and if the city itself were not by its very plan tied to a historic past, the problem would be less complicated. The very fact that Washington and Jefferson, L'Enfant and Ellicott, and their immediate successors, drew inspiration from the world's greatest works of landscape architecture and of civic adornment made it imperative to go back to the sources of their knowledge and taste in order to restore unity and harmony to their creations and to guide future development along appropriate lines. Indeed the more the commission studied the first plans of the Federal City, the more they became convinced that the greatest service they could perform would be done by carrying to a legitimate conclusion the comprehensive, intelligent, and yet simple and straightforward scheme devised by L'Enfant under the direction of Washington and Jefferson.

PART OF L'ENFANT MAP OF WASHINGTON (1791).

L'Enfant's plan shows that he was familiar with the work of Lenôtre, whose examples of landscape architecture, not only in France but also in Italy and England, are still the admiration of the world. We know, also, that L'Enfant had the advantage of those maps of foreign cities, 'drawn on a large and accurate scale,' which Jefferson gathered during his public service abroad, and we learn from Jefferson's letters how he adjured L'Enfant not to depart from classical models, but to follow those examples which the world had agreed to admire. In order to re-study the same models and to take note of the great civic works of Europe, the commission spent five weeks of the summer of 1901 in foreign travel, visiting London, Paris, Rome, Venice, Vienna, Budapest, Frankfort and Berlin. Among the many problems with which the commission is called upon to deal, there is not one which has not been dealt with in some one of the cities mentioned, and

by way either of example or of warning the lessons of the past have been brought to bear upon the present work.

On beginning work the commission was confronted by the fact that while from the first of October till about the middle of May the climatic conditions of Washington are most salubrious, during the remaining four and a half months the city is subject to extended periods of intense heat, during which all public business is conducted at an undue expenditure of physical force. Every second year congress is in session usually until about the middle of July; and not infrequently it happens that, by reason of prolonged or special sessions, during the hottest portion of the summer the city is filled with the persons whose business makes necessary a more or less prolonged stay



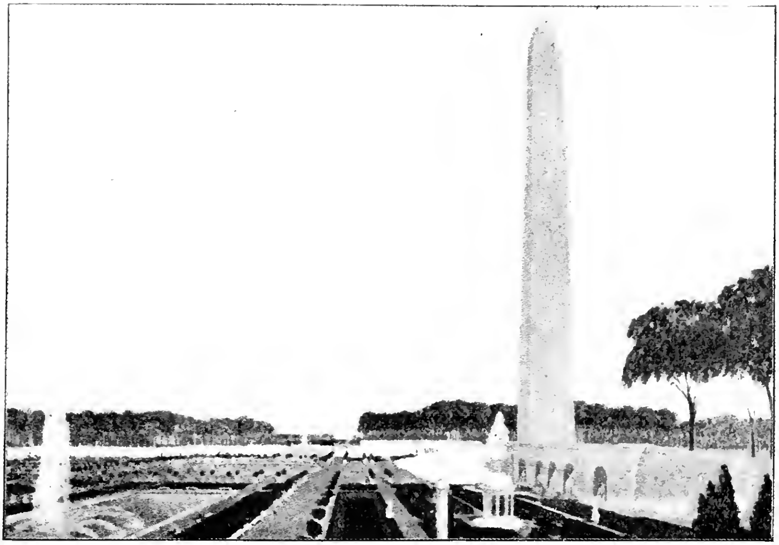
VIEW SHOWING THE PROPOSED TREATMENT OF UNION SQUARE, AT THE HEAD OF THE MALL.

in Washington. Of course nothing can be done to change weather conditions, but very much can be accomplished to mitigate the physical strain caused by summer heat. Singularly enough, up to the present time the abundant facilities which nature affords for healthful and pleasant recreation during heated terms have been neglected, and in this respect Washington is far behind other cities whose climatic conditions demand much less, and whose opportunities also are less favorable.

In Rome throughout the centuries it has been the pride of emperor and of pope to build fountains to promote health and give pleasure. Mile after mile of aqueduct has been constructed to gather the water even from remote hills, and bring great living streams into every quarter of the city; so that from the moment of entering the Eternal City until the time of departure the visitor is scarcely out of sight of beautiful jets of water, now flung upward in great columns to add life and

dignity even to St. Peter's, or again gushing in the form of cascades from some great work of architect or sculptor, or still again dripping refreshingly over the brim of a beautiful basin that was old when the Christian era began. The Forum is in ruins, basilicas and baths have been transformed into churches, palaces have been turned into museums; but the fountains of Rome are eternal.

If all the fountains of Washington, instead of being left lifeless and inert as they are during a greater portion of the time, should be set playing at their full capacity, they would not use the amount of water that bursts from the world-famous fountain of Trevi or splashes on the stones of the piazza of St. Peter's. At the Château de Vaux-



VIEW IN MONUMENT GARDEN, MAIN AXIS, SHOWING PROPOSED TREATMENT OF APPROACHES AND TERRACES, FORMING A SETTING FOR THE WASHINGTON MONUMENT.

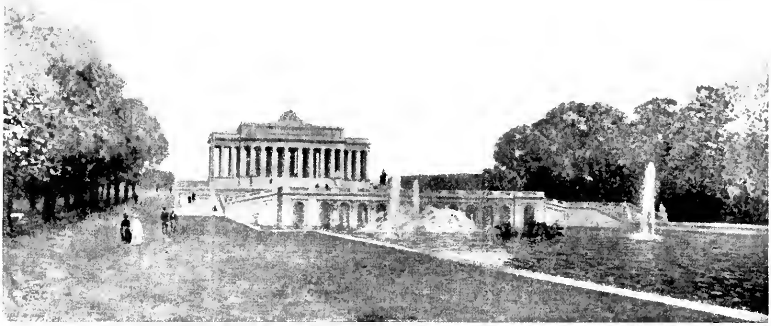
le-Vicomte, near Paris, the great landscape architect Lenôtre built cascades, canals, and fountains, using one twelfth of the daily water-supply of the District of Columbia. The fountains at Versailles are one of the most attractive spectacles enjoyed by the people of France.

The original plans of Washington show the high appreciation L'Enfant had for all forms of water decoration; and when the heats of a Washington summer are taken into consideration, further argument is unnecessary to prove that the first and greatest step in the matter of beautifying the District of Columbia is such an increase in the water supply as will make possible the copious and even lavish use of water in fountains.

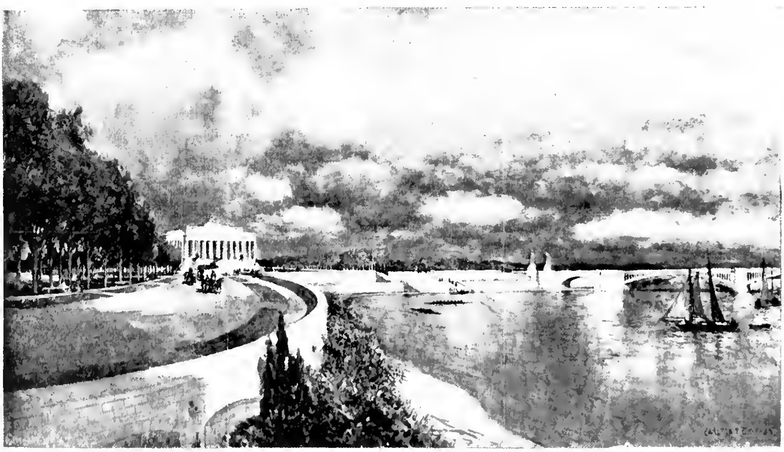
The location of public buildings has received the very careful consideration of the commission. In general terms their conclusions are:

1. That only public buildings should face the grounds of the Capitol.

2. That new department buildings may well be located so as to face Lafayette square.



View showing the Proposed Development of the Lincoln Memorial Site, seen from the Canal.



Proposed Development of Lincoln Memorial Site, seen from Riverside Drive.

3. Buildings of a semi-public character may be located south of the present Corcoran Art Gallery, fronting on the White Lot and extending to the park limits.

4. That the northern side of the Mall may properly be used by museum and other buildings containing collections in which the public generally is interested, but not by department buildings.

5. That the space between Pennsylvania avenue and the Mall should be occupied by the District building, the Hall of Records, a modern market, an armory for the District militia, and structures of like character.

The city of Washington, during the century since its foundation, has been developed in the main according to the plan made in 1791 by Major Peter Charles L'Enfant and approved by President Washington. That plan the commission has aimed to restore, develop and supplement.

The 'Congress house' and the 'President's palace,' as he termed them, were the cardinal features of L'Enfant's plan; and these edifices he connected 'by a grand avenue four hundred feet in breadth, and

ANACOSTIA MARSHES FROM BENNING BRIDGE, SHOWING MALARIAL FLATS TO BE EXCAVATED

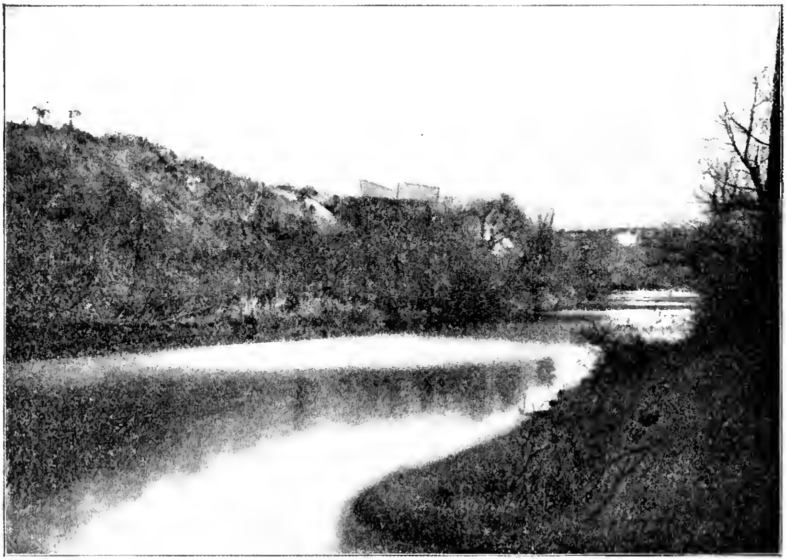
about a mile in length, bordered by gardens, ending in a slope from the houses on each side.' At the point of intersection of two lines, one drawn through the center of the Capitol, the other drawn through the center of the White House, L'Enfant fixed the site of an equestrian statue of General Washington, one of the numerous statues voted by the Continental Congress but never erected.

When, in 1848, the people began to build the Washington Monument, the engineers despaired of securing on the proper site a foundation sufficient for so great a structure; and consequently the Monument was located out of all relations with the buildings which it was intended to tie together in a single composition. To create these rela-

tions as originally planned was one of the chief problems of the commission.

Again, the reclamation of the Potomac flats, prosecuted since 1882, has added to the monument grounds an area about one mile in length from east to west; so that where L'Enfant dealt with a composition one and a half miles in length, the commission is called upon to deal with an area two and a half miles long, with a maximum breadth of about one mile.

By the inclusion of the space between Pennsylvania and New York avenues on the north, and Maryland avenue and the Potomac River on the south, the new composition becomes a symmetrical, polygonal or



Rock Creek, showing Possibility of Seclusion from Disagreeable Surroundings.

kite-shaped figure bisected from east to west by the axis of the Capitol and from north to south by the White House axis. Regarding the Monument as the center, the Capitol as the base, and the White House as the extremity of one arm of a Latin cross, we have at the head of the composition on the banks of the Potomac a memorial site of the greatest possible dignity, with a second and only less commanding site at the extremity of the second arm.

So extensive a composition, and one containing such important elements, does not exist elsewhere; and it is essential that the plan for its treatment shall combine simplicity with dignity.

CHANGES IN THE AGE OF COLLEGE GRADUATION.

BY W. SCOTT THOMAS,

TEACHERS COLLEGE, COLUMBIA UNIVERSITY.

THE belief seems to have become general that the American boy of to-day takes his first collegiate degree—A.B. or its equivalent —a good deal older than his father took his, and a great deal older than his grandfather. The present study was undertaken with a view to determining from actual records the measure and rate, if real, of this increase. The plates and tables that are presented herewith tell, in the main, their own story; my task will be little more than the making of a running commentary upon these.

The calculations are based upon nearly twenty thousand cases, and include the graduates of eleven colleges, representing all parts of the country except the extreme west. If undue weight seems to be given to the New England colleges, my excuse is twofold: first, the proportion of colleges that date back fifty years or more is much larger in New England than elsewhere; secondly, I have used all the published material I have been able to find, in the shape of alumni catalogues which give the date of birth of graduates. These have, moreover, been largely supplemented by private information very kindly furnished by the officers of colleges whose general catalogues do not come down to the year 1900.

The results are given in decade periods for the double reason that shorter periods are unwieldy, becoming too numerous, and because the longer period is more reliable. Two- or three-year periods often show what seems a very decided trend in a given direction; but this is in all cases decidedly modified if not entirely obliterated by the addition of the remaining years of the ten. The results thus win stability and evenness.

Before beginning the discussion of the tables and plates, one further word of explanation may be given. It will be noted that in Table I. and elsewhere the median age is used rather than the average age. The reasons for using the median age—the point above which and below which, respectively, one half of the students in each decade graduate—are evident. In the first place, the labor of finding the exact arithmetical average of the age of graduation of 20,000 students would be enormous; and when found it would not give us what we wish, viz., the age at which the students, or a definite percentage of them, actually

do graduate. It is evident that a few students graduating in a class above forty years of age—by no means an unheard-of state of affairs—would unfairly raise the average age of that class, since it is manifestly impossible to graduate twenty years below the normal age. Again, a class, or series of classes, may graduate a considerable number of its members below twenty, while a still larger number graduates above twenty-four or twenty-five. The curve of distribution of the ages of graduation will then resemble the letter M. Manifestly, in such a case, which occurs several times, the arithmetical average tells us nothing of value. Finally, the median age gives us the exact information that one half the students in question graduated at or above the given age, and the other half at or below it. The curves of distribution, moreover, given in the plates for all graduates and all colleges for the years 1850–59 and 1890–99, show exactly what percentage graduated at each age.

TABLE I.

MEDIAN AGES OF GRADUATION BY DECADES.

	Dartmouth.		Middlebury.		Bowdoin.		U. of Ver.		Adelbert.	
	Age.	No.	Age.	No.	Age.	No.	Age.	No.	Age.	No.
1770–79	23–0	78								
1780–89	23–1	150								
1790–99	23–2	336								
1800–09	22–6	323	22–10	76						
1810–19	22–9	330	23–1	194	20–4	106				
1820–29	23–1	328	23–0	187	20–8	258	22–4	59		
1830–39	22–5	384	23–4	242	21–7	289	22–7	80	23–0	41
1840–49	23–1	586	22–8	109	21–9	356	22–0	184	23–2	125
1850–59	23–8	558	23–3	121	22–1	335	22–4	168	23–0	98
1860–69	23–1	491	23–5	132	22–10	348	22–6	91	22–10	160
1870–79	22–10	593	23–4	111	22–5	321	22–6	98	22–9	217
1880–89	22–10	527	22–11	86	22–8	303	22–8	108	23–0	251
1890–99	22–9	678	23–2	125	22–7	481	22–9	215	22–9	156

We now come to a consideration of Table I.* The most obvious and surprising thing that strikes us at first sight is the fact that our

* In Table I., decade '1770–79,' equals Dartmouth 1771–79; decade '1800–09,' equals Middlebury 1803–09; decade '1830–39,' equals Alabama 1832–39, New York University 1833–39, Oberlin 1837–39, Wesleyan 1833–39; decade '1850–59,' equals in Syracuse 1852–59. In each case the corrected year marks the date of the first graduating class. In decade '1890–99' Adelbert includes only the years 1890–95; New York University, 1890–94; Syracuse, 1890–98. In Alabama University there were no graduates for the years 1866–71 inclusive. During several of these years the university was closed.

The data for the decade '1900– ' are as follows: Dartmouth, Oberlin, DePauw, each, class of 1900 only; Wesleyan, Alabama and Vermont, classes of 1900–01; Bowdoin, 1900–02. The whole number of cases in this 'decade' is 572.

In reference to the degrees included in the investigation, I have attempted to use only A.B., Ph.B. and B.S. In a few instances the last named degree

assumed great increase in the age of graduation, taken generally and so far as our material reaches, is absolutely non-existent.

The median age of graduation in Dartmouth, for instance, has in one hundred and thirty years fallen three months; in one hundred years the median for Middlebury has risen four months. But note that in 1830–39 the median for Middlebury was two months higher than now. In the case of Bowdoin, there has been a steady rise to a little over two years, which, however, reached its maximum in the decade beginning in 1860, and has since been falling. In seventy years, the University of Vermont median age has risen but two months; while in the same period that of Adelbert College has fallen three months. Again, we may compare the New York University with Oberlin College. While the age at the former has in sixty years risen one year and five months, in the latter it has fallen one year and seven months. It may be noted in passing that the number of graduates in the given

TABLE I.

MEDIAN AGES OF GRADUATION BY DECADES.

U. of Ala.		N. Y. Uni.		Wesleyan.		Oberlin.		De Pauw.		Syracuse.	
Age.	No.	Age.	No.	Age.	No.	Age.	No.	Age.	No.	Age.	No.
20–4	57	20–2	73	23–0	107	24–11	34				
20–3	126	20–3	147	23–3	231	25–6	122	21–7	63		
20–9	173	20–7	102	23–4	231	25–2	120	22–9	89	23–11	28
20–0	48	20–8	128	24–0	260	24–0	176	23–2	115	24–0	29
20–3	66	21–6	141	23–8	325	24–3	270	23–1	230	24–6	138
20–0	209	21–1	154	23–3	323	24–3	267	23–2	317	23–9	224
20–2	270	21–8	115	23–6	456	23–11	403	23–9	371	23–11	264

seems to be used as a semi-professional degree, implying for instance, that the student has taken an engineering, or some such course not purely 'cultural.' It seemed impossible to shut out entirely cases of the semi-professional degrees. The number of them is, however, too small to materially influence the results. In Dartmouth College the graduates of the Chandeler Scientific School are not included in the calculations, for the reasons above given. The justice of the exclusions above referred to is evident at once; for the examination is an attempt to show the changes that have come about in the college course as formerly understood. That is, when it did not include the study of a profession within itself, as several of the present courses do.

Only young men have been considered in my inquiry. It is interesting, however, to note that if young women had been included in the investigation, the averages and medians would have, in almost every case, been materially reduced. In other words, the young woman is either more highly selected as a student, or she meets with fewer hindrances external to her work while going through high school and college. At any rate, whatever the cause or causes may be, the young woman graduates are, as a rule, younger than the young men in the same college. This subject is worthy of a separate inquiry.

time is in Oberlin about double that in the New York University. Finally, we may call attention to the fact that in the University of Alabama and in Syracuse University, the age of graduation has remained practically unchanged, with a slight tendency to decrease.

So much for the general aspects of Table I. It will be of some interest to consider somewhat closely the changes that have come within the last two generations of college graduates, or since 1850. At this period all the colleges in our list are available for comparison; and it is since the beginning of this period that practically all the modern development of the American college has taken place. What happened before 1850, while it may be interesting, can not have the importance for us now that the changes of the past fifty years have.

At the outset, we note that of the eleven colleges in the table, the median age for one only remains quite unchanged—Syracuse. The following show increases, in months: Bowdoin, 6; Vermont, 5; New York University, 13; Wesleyan, 2; DePauw, 12; total, 38. The following show decreases, thus: Dartmouth, 11; Adelbert, 3; Alabama, 7; Oberlin, 15; Middlebury, 1; total, 37.

Table II.

Average of Median Age of Graduation for Past Fifty Years.

	1850-59	1860-69	1870-79	1880-89	1890-99
Dartmouth	23-8	23-1	22-10	22-10	22-9
Middlebury	23-3	23-5	23-4	22-11	23-2
Bowdoin	22-1	22-10	22-5	22-8	22-7
Univ. of Vt.	22-4	22-6	22-6	22-8	22-9
Adelbert	23-0	22-10	22-9	23-0	22-9
Univ. of Ala.	20-9	20-0	20-3	20-0	20-2
N. Y. Univ.	20-7	20-8	21-6	21-1	21-8
Wesleyan	23-4	24-0	23-8	23-3	23-6
Oberlin	25-2	24-0	24-3	24-3	23-11
DePauw	22-9	23-2	23-1	23-2	23-9
Syracuse	23-11	24-0	24-6	23-9	23-11
Av. of Totals	22-9.6	22-9.3	22-9.9	22-8.3	22-7.5

The net result of the changes that have come in the age of graduation in these fifty years is more clearly presented to the eye by Table II. Here is presented a view of the medians for all the eleven colleges, wherein each college is given an equal weight, regardless of whether it be a large or a small college. By this method then is avoided the overweighting which a large college, like Dartmouth or Bowdoin, would otherwise exert on the results. The results show that in only one decade is the average of medians as high as that of 1850–59. Moreover, the last two decades show a slight decreasing tendency, making a net reduction in fifty years of two months for all the colleges.

Thus far we have dealt with the median age of graduation as distinct from the average age, and reasons have been adduced to show why the

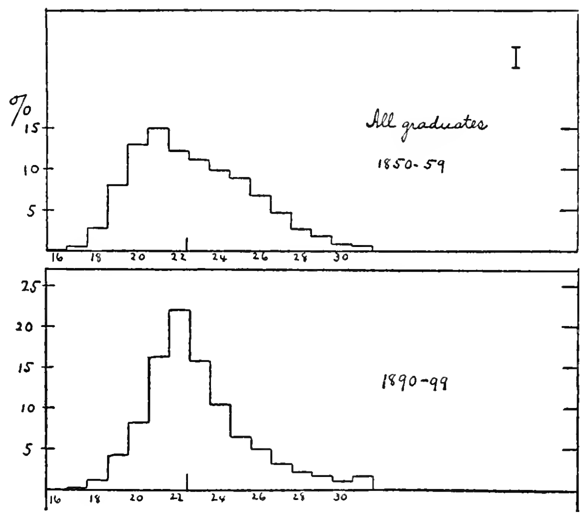
former is preferable to the latter as the measure in our present study. Inasmuch, however, as the arithmetical mean is the one in most common use, and further, as some may still feel that it, if investigated, would show the rise that has been supposed to exist, we will consider the data and results that Table III. shows. In this table are shown

TABLE III.

AVERAGE AGE OF GRADUATION FOR THE PAST FIFTY YEARS.

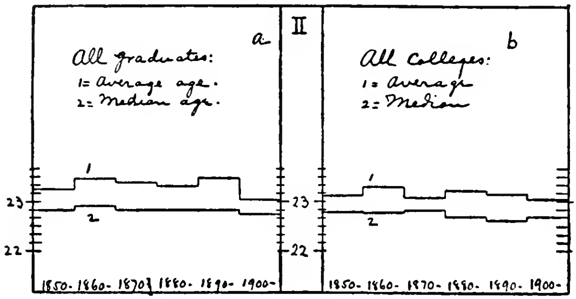
	1850–59	1860–69	1870–79	1880–89	1890–99	Cases.
Dartmouth	23–9.4	23–6.7	23–4.9	23–1.3	23–2.7	5362
Middlebury	23–8.1	23–6.5	23–5.8	23–6.5	23–8.1	1386
Bowdoin	22–6.4	22–11.7	23–0.0	23–1.6	23–2.4	2797
Vermont	22–11.5	23–3.3	22–8.6	23–3.4	23–0.2	1003
Adelbert	23–9.6	23–7.2	23–2.4	23–2.4	22–10.8	1048
U. of Ala.	21–0.0	20–1.8	20–2.4	20–3.6	20–6.0	949
N. Y. U.	21–1.6	21–2.3	20–8.4	21–7.5	21–10.8	860
Wesleyan	23–10.8	24–3.3	24–2.8	23–10.2	23–6.1	1933
Oberlin	25–0.7	24–7.5	24–5.3	24–8.7	24–3.9	1392
DePauw	22–2.4	23–8.4	23–8.4	23–9.1	23–10.3	1185
Syracuse	24–1.6	24–5.0	24–7.7	24–8.6	24–7.5	751
Av. of Totals.	23–1.3	23–3.4	23–0.8	23–2.3	23–1.9	

the arithmetical averages of each college by decades, supposing that the students graduating at any given year of age, say 22, are about equally distributed throughout the months of the year, thus giving an average for the given year of, say 22.5 years. With small numbers,



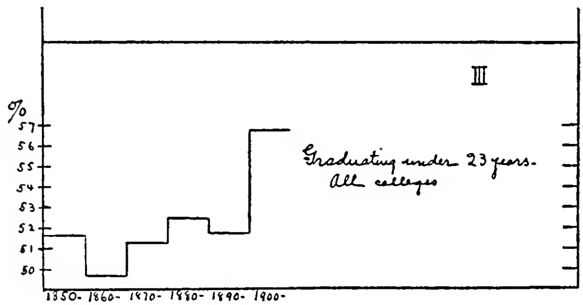
this assumption is not without its liability to error; but with numbers so large as we have, the errors are found by actual trial practically to negative each other; so that we can rely upon the results as being, for all practical purposes, and in the main, substantially correct.

The first striking thing to be observed in Table III. is the fact that the average age is a few months higher than the median throughout in the totals of all colleges. In the past fifty years, the average age of graduation has remained quite unchanged, while in the past forty years, the average has fallen one and a half months. This difference



is, however, probably too small to be in itself significant, so that we may conclude that there is neither any actual change in the average, nor any definite tendency observable towards rising or falling.

In the above discussion of averages, each college has been given the same weight as every other. Now, we may look at the same matter from another point of view. We may bunch all the graduates, as though

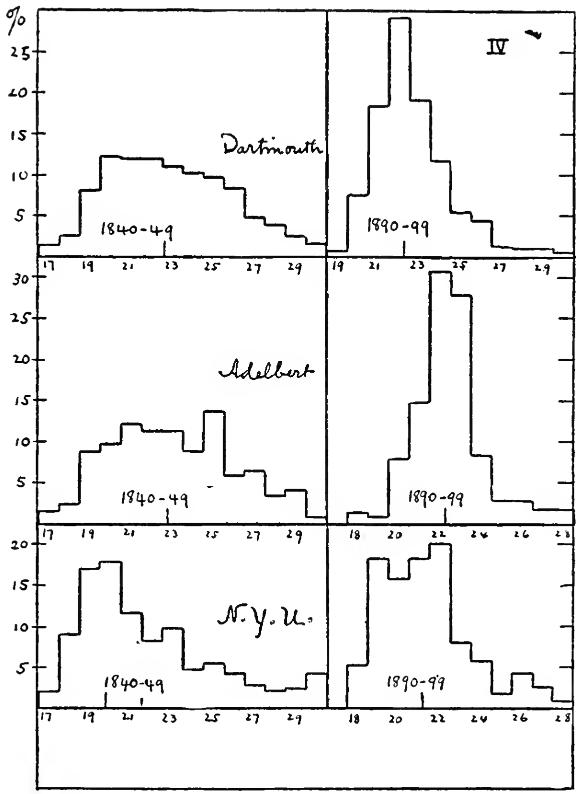


they were all students of one great college; and, still assuming that they will be about equally distributed through the months of any given year—an assumption which by the now very much larger numbers is made doubly secure—we may take the average for the five decades since 1850. By this method we obtain the following results:

	1850–59.		1860–69.		1870–79.		1880–89.		1890–99.		1900– .	
	Yr.	M.	Yr.	M.	Yr.	M.	Yr.	M.	Yr.	M.	Yr.	M.
Av.....	23	3.0	23	5.4	23	4.8	23	3.9	23	6.1	23	0.5

Even here, where every concession possible is allowed to the weighting of the averages by the few colleges which in the last decade have relatively much larger numbers, together with their consistently

higher average age of graduation than in the earlier decades, we still find no change of any significance. At the very best, or worst, the change in fifty years past has been only three months. While now, if we may use for the sake of further illustration the available data of the colleges for the decade beginning 1900, we find on an average three months less than that of 1850–59. The colleges included here are those seven which furnished for the decade 1890–99 over 81 per cent. of all graduates, and include all the colleges except New York University, Adelbert College, Middlebury College and Syracuse Uni-

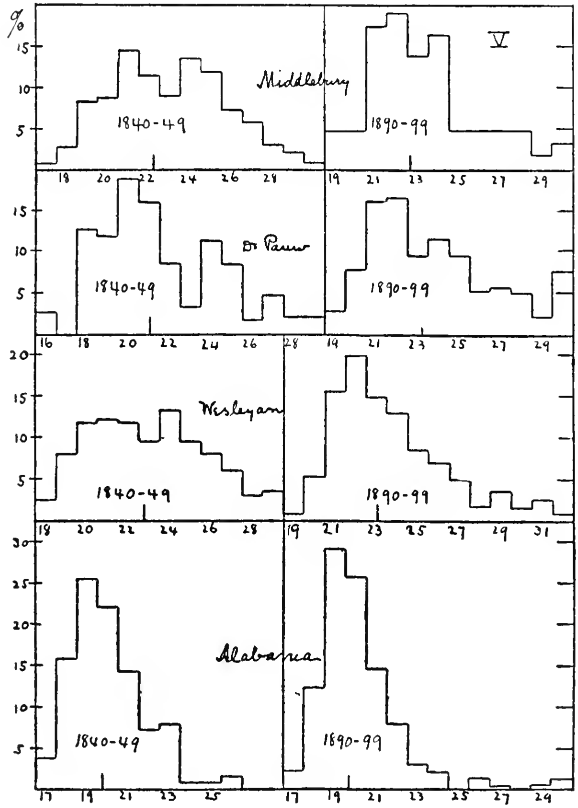


versity. It will be noted that all the largest colleges are included, and that of those omitted two are above and two below the average in the decade 1890–99.

We may now turn from the consideration of the tables to an examination of the plates. Plate I. shows the percentage of students actually graduating at each age—16 years to 31 years—in which last category are bunched for convenience all graduates of the age of 31 years or over—for the two decades 1850–59 and 1890–99, respectively. The upright line on the base in the twenty-second year marks the actual

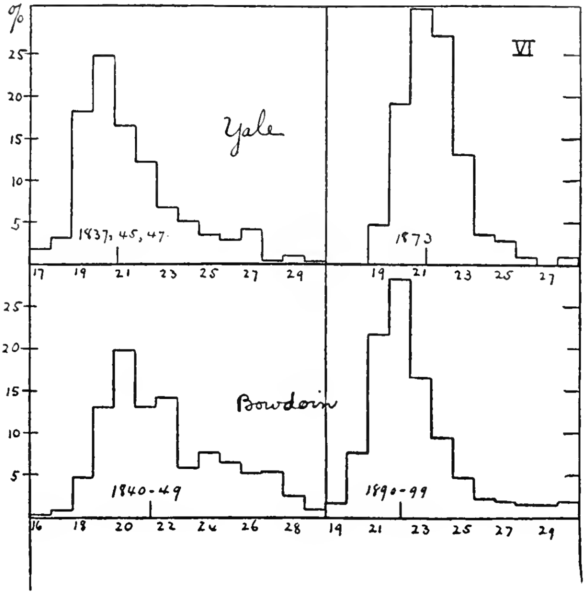
median age of graduation of all students for the decade. It will be noticed that its position remains absolutely unchanged. Perhaps the most noticeable exhibition presented by this plate is the pushing of the great bulk of graduates in the last decade into the comparatively narrow compass of the years 20–24, and the consequent great reduction of the numbers graduating above or below these limits as compared with the earlier decade.

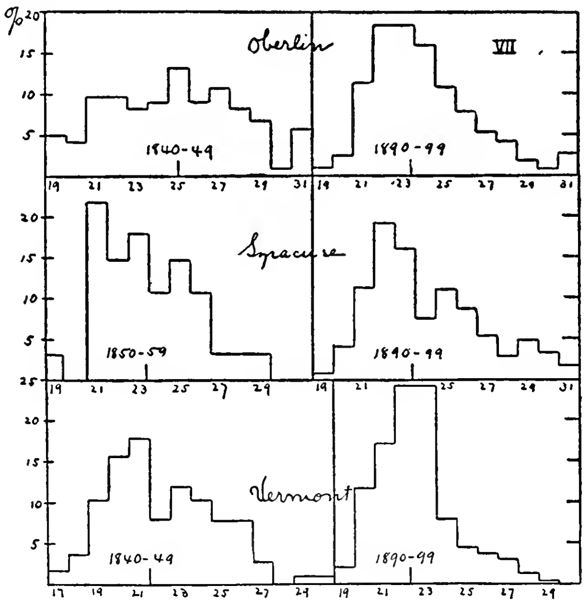
One further observation is worth making: At first sight it appears that the mode—the year in which the largest number graduates—is in



the first decade, the twenty-first year; while in the second decade this has been pushed up, and is now the twenty-second. In this there are two matters of significance. First, while the mode in the first decade is 21, the percentage here is still less than it is in the same year in the next decade, where the mode appears as 22; secondly, the reduction of the percentages in the years below the twenty-second in the second decade is largely due to the fact that in the first decade two or three colleges which have a high median age of graduation have in this decade

very few students, while in the last decade they have a relatively very much higher number of graduates, thus acquiring an undue influence in the second decade, and failing to exert this influence in the first





decade. This fact, which does not come out in this plate, becomes much clearer if we take decade 1860–69 for comparison with decade 1890–99.

Plates IV., V., VI. and VII. present the evolution of the individual colleges during the last five or six decades in the matter of concentration of the body of graduates into a few years. We may in a measure take the degree of this concentration as an indication of the homogeneity of the student body, and of the organization of the educational machinery that prepares the students for college. It will be noted that while there is the greatest difference in the degree to which the condensation has gone on in different colleges, there is, nevertheless, a distinct and uniform tendency towards this concentration, which must in every case be set down as a distinct advantage to the college. The ideal types may be said to be very nearly approximated by such curves as those of Yale, Plate VI., Adelbert and Dartmouth, Plate IV., and Alabama, Plate V. Such a curve as that of Dartmouth, which we may take as the type which all the other colleges more or less closely resemble, shows most clearly that the college has changed in sixty years from a place to which a young man might go for study at any age, to a place to which young men go as a matter of business, so to speak, and at a definite period of their life. In other words, the going to college has become a matter of social organization, with its very definite place in the life of the youth. The intermediate decades, which lack of space prevents our showing, present curves which show how gradually this change has come about. It seems, further, a safe conclusion to say that all the colleges that have not yet reached the high degree of concentration which some show are, nevertheless, distinctly destined to come to it, unless some unseen force changes their direction of development.

It should be noted, in passing, that an anomaly, such as the curve of Syracuse for 1850–59, is due to the small number of cases. There were but twenty-nine graduates in this decade.

Plate II. presents in graphic form the same facts that have been given in the tables. Division 'a' shows in the upper line, marked '1,' the average age of all graduates as presented in Table III., 'Average of Totals,' plus the data for decade 1900, so far as available, also referred to above. The second line, marked '2,' gives the actual median age of all graduates considered as students of one college. It will be noted that, while the median has remained practically uniform throughout, the average has varied, but with no marked tendency either up or down.

Plate II. 'b' presents the same facts as 'a,' except the units of comparison are now colleges instead of individual students. While, as would be expected from the small number of cases, the fluctuations are greater than in the 'a' division, the same absence of pronounced trend in either direction is easily observable.

There is one tendency in American education which it seems we may accept as established beyond cavil, viz., that for the future, the public high school will take the place of the old academy, as the institution in which the average boy will receive his training antecedent to entering college. In the days of our grandfathers, the prospective college student received his preparation for college either under the private instruction of his pastor, or in one of the academies of the time. In either case, the body of college-going boys was a highly selected one—a class who had both the tradition of the scholarly life and, to no small extent, the taste and opportunities to follow this tradition. Then, even more than now, the college turned out men whose future work was to be the ministry, law or medicine.

With the advent of the public high school and the growing tendency of colleges to accept its graduates for entrance to college courses, we should expect to find two or three changes in particular becoming manifest: First, we should expect to find the college-going students less selected along the lines of intellectual aptitudes and scholarly traditions; secondly, we should expect a greater scope of life employment among the college graduates; and thirdly, we should anticipate a natural advance in the age at which boys would go to college as a result of the above-named circumstances, with all that they imply. Now, our public school system is, for the most part, so constructed that the normal age for a boy to finish his high school course is in his nineteenth year, making his age of graduation from college between 22 years and 22 years, 11 months, inclusive.

From this point of view, it becomes important to examine our data with a view to finding out in how far these influences which would be expected to raise the age of graduation from college have been active over other conditions which have negatived them, or *vice versa.* Plate III. shows the percentage of students that actually graduated in all colleges under the age of 23 years, since 1850—the date at which the data for all our colleges become available. Comment is hardly necessary here. With the exception of decade 1860–69, which evidently shows the effects of the civil war, the trend has been unmistakably upwards. Even if we throw out the figures for 1900—which represent, as explained above, all the available data from the colleges that in 1890–99 furnished over 81 per cent. of all graduates—the trend is still unmistakably upwards.

Concerning the influences that have been instrumental in causing the marked rise in the median or average age of graduation in certain colleges in our list, it is not possible to speak with certainty for all. In the case of one or two, such as New York University and Bowdoin College, it would seem that the rise is due to an increase in the requirements for admission. In the case of certain other, pronouncedly

denominational institutions, as DePauw and Syracuse, there is one element separable from perhaps others that may be surmised, which has played an important rôle. This is found in the decidedly high average or median age of those young men who go into the ministry. The following shows the conditions in the two institutions just named:

	DePauw University (1). Syracuse University (2). Median of non-ministers.				Median of ministers.				Per cent. of ministers.	
	(1)		(2)		(1)		(2)		(1)	(2)
1850–59......	22	1	23	8	25	5	25	6	27.2	27.6
1860–69......	23	1	23	3	23	3	24	6	22.8	41.6
1870–79......	22	7	23	11	25	6	25	9	25.2	28.5
1880–89......	22	11	23	3	25	3	25	6	25.4	31.7
1890–99......	22	9	23	2	26	9	26	7	22.2	30.7

It thus appears that our medians for these two colleges as shown in Table II. would, with this element of disturbance removed, give quite different results. Thus the median of the last decade for DePauw would be lowered by just twelve months; while that of Syracuse for the same decade, instead of remaining the same as that of fifty years before, would be lowered by nine months.

While I have not been able to work over the data for the other denominational colleges completely enough to give the results here, there are nevertheless many indications that a similar state of affairs prevails, though probably in different degree.

In conclusion, we may sum up our findings as follows: The increase in age of graduation from college in general has been tremendously exaggerated. It exists only for certain institutions; while others show a corresponding decrease.

The normal age of graduation, as our school system is constituted, is below twenty-three years and above twenty-two; our results show that more students graduate now within those limits than ever before; that the gradually organizing secondary education tends to make this percentage increasingly larger. (Nearly 85 per cent. of all graduates of the Johns Hopkins University in the twenty years since its founding to 1899 have been within these limits.)

If entrance into professional life is later than formerly, the cause must be sought elsewhere than in the college and preparatory school.

Whereas it was once *possible* for a boy to graduate from college at sixteen or even younger, though very few really did so, this is true no longer. But the young man now, as a consequence, leaves college with very much higher academic attainments, and but little if any older than was his father, or even his grandfather.

All colleges show, in different degrees, an increasing diminution of range in age of graduation. This shows that the secondary education is becoming better organized.

If now, the age of graduation which we have shown to be the prevailing one, viz., 22.5 years, be deemed still too old, three means of reducing this would seem to be possible: First, cut off one year from the college course, without lowering the entrance requirements; secondly, in view of the far greater efficiency of the secondary school, reduce the entrance requirements to college and, retaining the four years' course, permit the boy to enter college, say, a year younger; thirdly, drop one year from the college course, increase the length of the actual weeks of residence and instruction to thirty-eight or forty, and endeavor to disabuse the mind of the average collegian of the belief that college is a place to dawdle and loaf four years for the sake of a degree that he does not earn, but which he generally gets just the same. The college would then have a serious opportunity to prove its right to existence, and if it succeeded, the present dilettantism of college life would tend to disappear.

One further suggestion we may venture to make. Every boy that has the native capacity to do college work should be put into the high school in the fall after he is fourteen years old, regardless of whether he has done all the prescribed grammar school work or not. If he can not then get ready for college by eighteen, don't let him go to college. He is not cut out for the strenuous intellectual life.

EDUCATION NOT THE CAUSE OF RACE DECLINE.

BY GEORGE J. ENGELMANN, M.D.,

BOSTON.

YALE graduate families have been growing steadily smaller, says Mr. Clarence Deming in an interesting review (*Yale Alumni Weekly,* March 4, 1903) based upon class returns which show a gradually decreasing fecundity from 1810 to 1880: this statement together with the small size of the Harvard family as revealed by the report of President Eliot, has justly directed attention to the apparently sad family condition prevalent among college graduates, or, as it has been expressed, among 'the highly educated portion of our population'; and it is generally assumed that this small family size pertains mainly to the highly educated, that conditions are better among the—let us say—*less* highly educated. It has been inferred that college graduates' families stand alone in not reproducing themselves and 'not adding to the increase of the population,' and that other portions of the population do so reproduce and add to the increase. Accepting this, it naturally follows that education, which has caused the mischief, must be suitably regulated. One suggestion is to shorten the term of study. But are the premises correct?

Speculation has been rife, and the small size of the graduate family is discussed far and wide without ever a thought as to what the conditions among the great mass of our native population may be, and yet it would be well to establish the facts in the case, and to determine the existence of an exceptionally low fecundity among college graduate families before deciding on cause and cure.

True, the average graduate family does not reproduce itself, but no more does that of any other group of our native American population, and the surviving family, the net family of the college graduate is not smaller, but actually larger than that of his less highly educated brother. This points to an unusually low rate of reproduction for the entire native-born element of our population; in fact the conditions now existing among the American people are worse than those found in any other country. They are those of a decadent race, those of Greece and Rome in the period of decline; and again and again, within the past few years, have I urged that the attention of thinking men be seriously given to a consideration of the alarming status attained.

To present this properly, and demonstrate the part taken by each group in the movements of population, it is essential to consider class reproduction; not alone fecundity and size of family, but marriage rate as well must be taken into account. In both the status of the college graduate as a class is most creditable, and at variance with all that has been assumed, though conditions differ greatly in individual institutions.

The marriage rate is surprisingly high for the highly educated, or, to be precise, for 4,408 college graduates, even if the 88.7 per cent. of Brown '72 and the 87 per cent. of the Bowdoin classes of 1875 and '77 is above the average, which is 79.4 per cent. for 16 Yale, Brown, Bowdoin and Princeton classes, and 75.4 per cent. if we include the 9 Harvard classes '72–'80 with their low marriage rate of 71.4 per cent.

My investigations show that the college graduate, the academic graduate (conditions differ for scientific graduates), marries 7–7½ years after leaving college, at nearly 30 years, so that we can compare him with the age group 30–39 of the native American male, with a marriage rate of 68.8 per cent., closely approximating the Harvard average.

TABLE I.

MARRIAGE RATE. 30 CLASSES, 4,408 GRADUATES.*

Group 40—49 years of age, approximately.

3,009 College Graduates, 22.5–47 years of age.					Population at large.	
27 Classes from 5 Colleges.	No. of Years out of College.	Number of Classes.	Year of Graduating.	Per Cent. Married.	Per Cent. Married.	Male population of Massachusetts, 40–49 Years of Age.
Brown	25	1	72	**88.7%**		
Bowdoin	25	2	'75 and '77	**86.9**		
Yale	25	1	73	**82.3**		
Bowdoin	25	1	61	**82**	**79.02**	Native born.
Princeton	25	1	76	**80**		Foreign born.
Yale	25	10	'60–'79	**78.4**		
Harvard } 25 years	**71.6**	9	'72–'80	**71.4**		
Harvard } 20–23	**71.1**					
545 College Graduates, 10–11 years out of College.						30–39 years.
Harvard	10	1	79	**54.2**	**68.8**	Native born.
"	11	1	86	**51.9**	**74.5**	Foreign born.
Princeton	10	1	91	**75.4**		

Group 20—29 years of age, approximately.

848 Graduates 7½ Years out of College, 22.5–30 Years of Age.				Male Population of Massachusetts, 20–29 Years of Age.	
Princeton 7½	1	'95	**43%**	**27.7%**	Native born.
Harvard 7½	1	'95	**26%**	**36.2%**	Foreign born.

* This table is arranged according to rate of marriage.

Accepting 22.5 as the age of graduating,* graduates of 1895, 7½ years out of college would have attained the age of 30 and must have married between the ages of 22.5 and 30, so that they are comparable to native males of the age group of 20 to 29, with a marriage rate of 27.7 per cent. The Harvard class of '95 shows a somewhat lower rate, 26 per cent., but the Princeton class of the same year a very much higher one—43 per cent. The Princeton class of 1891, ten years only out of college, has 75.4 per cent. of its members married, more than any Harvard class as far back as '72 shows after its twenty-fifth anniversary.

These figures, though small and bearing on only a few of the many colleges, certainly indicate that the male college graduate in this country is not more given to solitary life than the native male of all classes throughout the state and that the supposition of Rubin and Westergaard for Denmark, that the marriage frequency of the professional class is only two thirds that of the average does not hold good for the American alumnus, and probably not for the professional classes of the United States. It shows that a larger per cent. of college graduates marry, and those of some colleges marry in such numbers that it would appear that they marry as early as does the average native male, because the percentage in the earlier years is the same for average males and graduates.

The marriage rate of Harvard graduates alone differs from that recorded for all alumni investigated, from Princeton, Yale, Brown and Bowdoin, so that the alumnus of this institution can not well serve as an exponent of the highly educated part of our population, or even of the average college graduate, differing distinctly from this group and less than that of the native male of the same age throughout Massachusetts with a marriage rate of 79 per cent. (I recall that for purpose of comparison with the 25 year graduates, I have taken the age group 40 to 49 of the native population, which presents the highest marriage rate, 79.02 per cent.)†

* 22.5 years is the average age of graduating for the Princeton classes 1901–02, 22.6 for Yale classes 1882–92, 22.8 for Yale 1892–02; for a crude average 22.5 will answer. For Harvard the age of entering is 19 with a probable 22.9 for graduating, an approximation necessitated by the non-existence of authoritative data.

† My figures are based on a study of 4,408 alumni from leading eastern colleges: 848 graduates 7½ years out of college, 545 10 and 11 years out and 3,015 25 years out, and I have been careful to record rates for all older classes, *i. e.*, graduated more than 25 years ago, as given at the time of the twenty-fifth anniversary, for purposes of comparison on a just basis. This explains some trifling discrepancies which may be observed between my figures and others recently published. To me it seemed the only correct procedure. The Harvard classes '78, '79 and '80 are reported on a 23, 21 and 20 years' basis respectively, making but a slight difference, as may be seen by a study of Princeton '91.

The fecundity of graduate marriages, the total number of children born (gross fertility) is a trifle less than that of the average native marriage, rarely above, as in the Princeton class of '76, with 3.2 children: it is 2.55 for the Yale classes 1860–80, 2.4 for Brown '72, 2.07 for Harvard 1872–80, 2 for Bowdoin 1875 and '77 as compared to 2.7 for the native American family of Massachusetts according to the refined statistics of Kuczynski, which show a greater fecundity for the native population than is proved by my studies in St. Louis and those of Dr. Chadwick in Boston, 2.1 and 1.8 respectively.* Even granted so high a fecundity as 2.7 for the average native family, the *surviving* children under this assumption are only 1.9 to the family; the lower death rate for children of the cultured and well-to-do—10 per cent. in college graduate families against 28.5 per cent. for the lower classes—reverses the relative status when we consider the actual family size; the number of surviving children, the net fertility: this is greater for the graduate family (see Table II.); and it is the surviving children who serve to reproduce the population. 1.9 (1.92 precisely) is the largest possible number for the native population of Massachusetts, as compared to 2.7 for Princeton, 2.28 for Yale, 2.26 for Brown, 1.86 for Harvard 1872–80, 1.88 for Bowdoin.

TABLE II.†

DEATH RATE IN FAMILIES OF PROFESSIONAL AND LABORING CLASSES.

Parentage.	Number of Children to each Married Couple.		Death.		
	All Born.	Surviving.	Number Died.	Death Rate Per Cent.	
3015 College Graduates	*2.34*	*2.1*	0.24	10 %	United States.
Population of Mass. — Native Born.	*2.61*	*1.92*	0.69	28.5	United States.
Population of Mass. — Foreign Born.	*4.53*	*3.01*	1.52	33.4	United States.
Denmark. — Upper Class	*4.52*	*3.31*	1.21	26.7	
Denmark. — Artisan and Laboring Class	*4.95*	*3.14*	1.81	36.6	
Berlin. — Military or Upper Class				12.84	Europe.
Berlin. — All Children				24.72	Europe.

* My own data are obtained direct from the mother and will more correctly represent existing conditions than figures like those of Kuczynski secured by additions for possible omissions to state registration records. I must add that they show, on an average, the number of children borne in 10 years of marriage, which should be very near the total.

† This table does not quite indicate what I wish to show, as the mortality rate compared with that of the graduate family is not the mortality in families of the lower and laboring classes, but in those of the entire population, which includes the educated and professional classes.

Graduate families are, as these figures show, not only not smaller, but they are larger than those of the native-born American population of all classes, and larger than would have been expected from what is known of the relative fecundity of rich and poor in other countries. The relation of the educated and professional classes to the masses, to the laboring or artisan class, however, is the same as that shown for Copenhagen by Rubin and Westergaard, the total number of offspring born being somewhat larger for the family of the artisan; the real family, the number of the surviving, on the contrary, being somewhat larger for the educated, for the reason of the lower death rate in such families.

The rate of child-birth has been decreasing in college families, but it has been decreasing throughout the civilized world, slowly in the old world, with astonishing rapidity in the new, that is, among the native American-born of our population, until it has reached a minimum; the number of children to the native American family of all classes (and in this lies the danger) being less than it is in any other country, France even not excepted, which has long been known to be at the point of stagnation.

These are facts; the figures have all been elaborated and repeatedly presented so that any hypothesis is unnecessary. The American population is not holding its own; it is not reproducing itself, and the highly educated do not stand alone in this.

Important as is the fact of our racial decline, bearing as it does upon our future as a nation, it has not been observed, because of the fair general rate of child-birth, due to the much greater fecundity of the foreign element, which is from 2 to 2½ times that of the native, thus bringing the total birth rate of the state to an equality with that of France,—22.4 per 1,000 living population, or above it.

This is true of six representative states, for which we have fairly reliable statistics; in some, the birth rate is distinctly higher than that of France, as high as 26 and 28 per 1,000, but even in such states, that of the native-born is far below that of France. So in Massachusetts, with a total birth rate for the state of 27.78, practically 28 per 1,000 living population, that of the native-born is only 17, whilst that of the foreigner is over 52 per 1,000.

The net fertility, the total number of children born is 2.1 in France, and for the native population of the above state it is said to be 2.17 for 3,015 graduates from 25 classes 1870–80, in five eastern colleges it is 2.34. But these figures may be ignored, as it is not the total number of children born, but the *surviving* who add to the population, and it is these whom we consider: the *surviving* children of college graduates, 2.7 for Princeton, 2.28 for Yale, 1.86 and 1.88

for Harvard and Bowdoin, respectively, must be compared with the number of surviving children for the native American population of the state of Massachusetts, which is 1.9, less, according to my own observations.

Less than 2 surviving offspring to reproduce the race for all native-American marriages, 2.1 for those of the limited group of college graduates!

This indicates a remarkable change since the days of Benjamin Franklin, who tells us that 'one and all considered each married couple in this country produced 8* children.' Though this is not a conclusion drawn from statistical study, it is yet indicative, and in harmony with my own deduction from genealogical records. Whatever the precise figures be, all observations agree as to the high fecundity of the American colonies, and tell of the great change which has taken place in one short century.

From conditions better than those in any other country, five and more children to the family, such as led to the Malthusian theory of superfecundation and to the fear of over population of the earth's surface, we have passed in hardly one hundred years to our present condition, with a fecundity for the native-born below that of any other country, such that the American race is unable to reproduce itself with a birth rate of 17 per 1,000 population,† hardly 2 children to the family!

These facts I first presented in 1901,‡ with records up to the end

* Let no one discredit this and call it impossible! Though surprising to us with a knowledge of the present, these figures are even exceeded at this day by the French-Canadian with a fecundity of 9.2 children to the family, as I gather from a study of one thousand families found in the records of Quebec life insurance companies: 9.3 for the rural, 9.0 for the urban population, is the fecundity of the child-bearing woman, not the fecundity per marriage, but nearly so, as sterile marriages are rare. The birth rate of the Russian peasantry in the Kaluga district, near Moscow, is 7.2 children to the marriage. Throughout Norway it is 5.8 at the present time, as much as it was in the American colonies at the time of the Declaration of Independence.

† That the native population is dying out, and that at an alarming pace, is evident, not alone from a birth rate much lower than that of France, but also from a comparison with that of Berlin. In France the birth rate was 22.5 per 1,000 living population; that of the native population of Massachusetts is 17 per 1,000; in Berlin, 1891–95, with *10 births for every 100 women of child-bearing age*, the births were one ninth behind the number necessary to keep the population stationary, whilst in Massachusetts the birth rate is *much lower, 6.3 births for 100 adult American born women of child-bearing age*. The result is self-evident.

‡ The subject has been treated in the following papers by the writer: 'The Increasing Sterility of American Women, with Increase of Miscarriage and Divorce, Decrease of Fecundity.' Engelmann. *Jour. of the Amer. Med. Assoc.*, October 5, 1901. 'Decreasing Fecundity Concomitant with the Progress of Obstetrics and Gynecology.' Engelmann, *Philadelphia Med. Jour.*, January 18, 1902. 'Birth and Death Rate as influenced by Obstetric and Gynecic Practice.' Engelmann, *Boston Med. and Surg. Jour.*, May 15, 1902.

of the eighteenth century, when the decline began, and at the same time I published complete statistical data for the end of the nineteenth century, when the lowest level had been reached.

I have shown that a gradual decline had already taken place during the colonial period from 6 and more children in the seventeenth century to 4.5 at the end of the eighteenth; then 2 at the close of the nineteenth; data for the intervening period I had none. It seemed reasonable to conjecture a gradual decline with developing civilization and rapidly increasing luxury of life, but proofs were wanting.

The Yale records fill the gap, and supply the intervening data I had so far persistently but vainly searched for; they distinctly portray the gradual decrease in the rate of child-birth and enable me to complete the table, period by period, which shows the remarkable changes that have taken place in family life in this country. To this the highly educated portion of our population is no exception. The decline is general, not confined to any one element, it is the same for college graduate and laboring class, for all American-born, for highly educated and less highly educated, so that higher education can not be the causative factor.

This table presents a startling record for a young and vigorous community, and it is but natural that we should ask for the cause of this rapid decline in birth rate among all classes of the American-born: where are we to seek the explanation? It can not be in physical inability, though the ravages of venereal disease are leaving their traces more clearly with increasing civilization and centralization, and constantly add to the number of the sterile. (This is 2.5 per cent. among a simple, hard-working people in the interior of Russia (Kaluga), and in Norway, whilst 20 and 25 per cent. of marriages are barren in the civilized and infected communities of the United States and of France.) I find 25 and 30 per cent. of families barren among the married graduates of large and centrally located colleges, as low as 9 per cent. in a Princeton class with high marriage rate and large families, an exceptionally healthy condition when we remember that 20 per cent. of all native marriages in the entire state of Massachusetts are childless.

The cause for this decline in family size can not be sought in the increased age for marriage, as this is delayed for all educated and professional men in this country as in England by nearly three years, from 27.2 to 30 for the male, and for the educated female from 24.3 to

* This steady decrease in the number of offspring in college graduate families is admirably shown by Professor Thorndike in his article on 'Decrease in Size of American Families' (POP. SCIENCE MONTHLY, May, 1903). Unfortunately he does not give the number of surviving children and pictures only graduate families.

TABLE III.

RACE DECLINE. DECREASE IN SIZE OF THE AMERICAN FAMILY.

Period of Observation.	Locality or Group.	No. of Cases.	Number of Children to Each Married Couple. All Born.	Surviving.
Am. Colonies	Benjamin Franklin.		8	
1700–1750	Genealogical Records.	503	6.6	
1750–1800	" "	784	6.1	
"	Am. Colonies (Sadler).		5.2	
"	New York State.		5.2	
1726–1779	Hingham (Town Rec.).	521	4.3	
1727–1784	Salem " "		4.6	
1783	Hingham (Holyoke).		4.6	
1800–1830	Genealogical Records.	213	4.6	
1804–1811	Portsmouth.		4.3	
1810–1842	Yale Grad. Class Rec.	447	4.13	
1842–1860	" " " "	839	3.33	
1861	Bowdoin " "	45	2.62	*2.35*
1860–1879	Yale Grad. " "	1104	2.55	*2.28*
1872	Brown " " "	53	2.45	*2.26*
1876	Princeton Gr. " "	118	3.2	*2.7*
1872–1877	Harvard " " "	888	2.21	*1.97*
1877–1880	" " " "	513	1.87	*1.66*
1885	State of Mass. { native-born.		2.69	*1.92*
	{ foreign-born.		4.5	*3.01*
1870–1880	Boston Labor Class, Chadwick.*	1374	1.9	
1870–1890	St. Louis Labor Class, Engelm.*	804	2.1	
"	St. Louis Higher Class, Engelm.*	114	1.8	
1900	Boston Upper Class, Engelm.*	600	1.8	*1.8*
1885	Female Col. Grad., Wright.*	804	1.3	
1900	Female Col. Grad., Smith.*	343	1.8	*1.6*
	Female Col. Grad., England.	58	1.5	

From table of Prof. E. L. Thorndike excluding families where husband died in first 10 years of married life—for Middlebury and N. Y. Univ., for Wesleyan all married are taken.

All Children Born.

	Middlebury.	Wesleyan.	New York University.
1803–09	5.6		
1810–19	4.8		
1820–29	4.1		
1830–39	3.9	4.5	4.0
1840–49	3.4	3.3	3.2
1850–59	2.9	2.2	2.9
1860–69	2.8	2.6	2.5
1870–74	2.3		
1875–79	1.8		

26.4, but as the number of surviving offspring is not less, this delayed marriage can not be looked upon as a factor in determining the small size of the graduate family. The cause is not to be sought in education, in so far as the male is concerned. The educated female is in a different class; the fecundity of the female college graduate in this country is lower than that of any other native group, and this low birth rate holds good for her English sister as well, the very small size of her family—smaller than that of the American alumna—standing out in striking contrast with the much higher fecundity of the English people, which is nearly double that of the native-born of the United States.

Family shrinkage seems clearly referable to the strenuous, nerve-racking life of the day, to the struggle, not for existence, but for a

* Average 10 years of married life.

luxurious existence, to the ever-increasing desire for the luxuries of life and the morbid craving for social dissipation and advancement. It is due, as plainly expressed and openly advocated by many, to the desire to have no children or only such a number as husband and wife believe in their wisdom suitable and adapted to their ideals of comfort, and to their supposed financial possibilities; the most important factor is the "deliberate and voluntary avoidance, the prevention of child-bearing on the part of a steadily increasing number of married couples,* who not only prefer to have but few children, but who 'know how to obtain their wish' " (Dr. John S. Billings). Professional observation and the plainly expressed ideas of men and women who do not hesitate to make known their views substantiate the above, as does the startling decrease of fecundity and the corresponding increase in sterility in the face of the scientific progress of the day in all that pertains to the physical well-being and health of woman. This decrease of fecundity in the face of advance in obstetrical and gynecological science, which should lead to a healthier condition of the child-bearing organs—a decrease confined to one element of the community, the native American—clearly proves the condition to be one determined by the volition of that element. Families are small among all classes of the native-born, large among all classes of the foreign-born population, showing that the cause of this low fecundity is not universal but it is one confined to the native element only; this limiting of the small family to the native of all classes in itself would prove that education is not that cause, were such proof not made needless by the fact that the family of the educated man is actually larger than that of the native male throughout the state.

Let us no longer beat about the bush and attribute the low fecundity now prevailing to later marriages and higher education. This explanation has been accepted because it is a tradition and universally credited; it is not so in other countries, and it has never been proved to be so for the United States. Theoretically later marriage must, it would seem, lead to the lowering of the birth rate. Facts plainly disprove this, and why should higher education lessen the size of the

* I have used the word *couples* intentionally, though in the original it is *women;* Dr. Billings says that the cause of declining fecundity is in the 'voluntary prevention of child-bearing on the part of a steadily increasing number of married women,' indicating that the *wife* is mainly at fault, whilst in truth *it is the husband* to an equal and *even a greater extent*, according to my observation.

In defense of the American woman it is but right to call attention to this fact and to correct the false impressions which are prevalent. This assertion is substantiated by experience and by the carefully prepared Michigan registration reports.

family as all seem to assume? Because the years of marriage are less? This is a hasty assumption as will appear when we recall that all children are born on an average within 7½ years after marriage, some authorities even say within 5 years. Accepting the longer term of 7½ years, this leaves the alumnus who marries 7 years after graduating in his thirtieth year, at 37½, and his wife, who marries at the latest at 26.4, in her thirty-four year. The end of the average child-bearing period falls accordingly for both the late marrying graduate and his spouse, still in the most vigorous period of life, 37½ for the educated male, 34 for the female, not so late as to interfere in any way with the family prospects. This is true for the college graduate: for the entire highly educated portion of our population I have no data and make no assertions. No figures are available for a group such as this, and this must be noted as the family size of this class has of late been considered. It is too comprehensive a term, and has been somewhat indiscriminately used in recent discussions of race decline; even far-reaching conclusions bearing upon this large group of the highly educated have been based upon data derived from the graduates of a single institution. Not even from those of several institutions if under similar conditions or even if of the same sex are we warranted in judging of the entire highly educated part of our population. The female college graduate must be classed among the highly educated, and the number of children in her family is below that of the native population; it is lower than that of any other group, whilst that of the average male graduate family is higher. Then again the college alumnus can not without further investigation be accepted as a standard, for even the highly educated male, as appears from the facts presented by Professor Dexter in his recent study of 'High Grade Men: in College and Out.' He shows that hardly more than one third, 37 per cent. of the 8,602 supposedly successful and prominent Americans mentioned in 'Who's Who' are college graduates, and only 2.2 per cent. of all now living alumni are included among these 8,000 supposedly higher type and most representative of living Americans. Regardless of this the variation in marriage and birth rate of the different elements of this group of the highly educated make it impossible to consider them jointly.

These facts, together with the limited data on hand, make it impossible as yet to reach conclusions of any kind as to the part taken by the highly educated portion of our population as a class in race reproduction; it is the male college graduate whom we here consider and compare, not with the male of the entire population, but with the native-born American only. I emphasize this as the two groups, the native- and foreign-born of our citizens differ widely as to the part they

play in reproduction of race. If the term highly educated is here used it refers solely to the college graduate.

A high marriage rate and an average of 2.1 surviving children to the graduate family as compared to 1.9 for the native-born male throughout the state tells us plainly that, contrary to all theory and supposition, higher education does not mean diminished reproduction. It is the American nationality that stands for lessened marriage and low birth rate, in striking contrast to the foreign-born of our citizens with families of from 3 to 5 children, 4.5 in Massachusetts with 3 surviving, and this is true for all classes of foreign-born.

Graduates as a group make an exceptionally good showing, and college alumni are to be congratulated upon the standard maintained; the net fecundity is greater, family size is larger than that of the general native population and marriage rate of some groups is higher, so that reproduction is more nearly approximated by the college graduate family. Contrary to European statistics for professional men, who, as already stated, are assumed to have a marriage rate two thirds less than the average male of the population, class reproduction for college graduates is higher than it is for the population at large.

The average marriage rate for 1,614 graduates of the classes 1870–77 from Yale, Princeton, Brown and Bowdoin is 79.4 per cent. and for a corresponding group of Harvard graduates, 1,401 of the classes 1872–80, it is 71.4 per cent., a rate so much lower than that for graduates at the other institutions named that we must differentiate. The average of these 3,015 alumni of both groups is 75.7 per cent.

The marriage rate of Harvard graduates varies so much from that of the alumni of all other institutions so far investigated that the Cambridge graduate can evidently not serve in this respect as an index for family conditions among college men any more than he can be looked upon as representative of that other element of the highly educated portion of our population, the female college graduate with a marriage rate of from 30 per cent. to 50 per cent. or, for still another, the highly educated man who has never received an academic degree and this, as has recently been shown, is a surprisingly large number in this country. The general marriage average of 79.4 per cent. for a group of graduates from four colleges and 71.4 per cent. for Harvard alumni must be compared with 79.02 per cent. for the native male population of the age group 40–49 years, and is greatly to the credit of college men. By reason of this high marriage rate the number of surviving children for 100 graduate members of a group or class, married and unmarried, is larger than it is for the less highly educated and in fact larger than it is for all other elements of our native male population, even where the number of children

to the married couple is the same; to this the Harvard graduate is an exception; with both family size and marriage rate lower than the graduate average and lower than that of the native-born male of Massachusetts (of a comparable age group—40–49 years), reproduction per class is naturally less. A Princeton class, if we may take '76 as an example, more than reproduces itself: it reproduces not alone the married couple, 2.7 surviving children to each, but more than reproduces the entire class, 2.3 to each class member, married and unmarried (2.3-net class reproduction). Brown just reproduces itself with 2.26 living children to the married graduates and precisely 2 to each member of the class.

All classes later than 1870 of other institutions so far considered fail to reproduce themselves, most so Harvard alumni. Yale graduates very nearly reproduce themselves with 2.28 surviving children to the married graduate and a net class reproduction of 1.78 (*i. e.,* for each member of the class). Next comes the single Yale class of '73 with a class reproduction of 1.57 children. The two Bowdoin classes 1875 and '77 are represented by 1.5 and the 9 Harvard classes 1872–80 by 1.3 children for each graduate, married and unmarried (1872–77 by 1.4 and 1878–80 by 1.19 respectively).

A great decrease has indeed taken place in the birth rate of graduate families, but not quite to the same extent as among other groups of the same social grade: the wealthy or leisure class, the well-to-do invariably do less towards reproducing themselves than does the population at large; the college graduate, the highly educated male, does more.

TABLE IV.

REPRODUCTION OF CLASS AND RACE.

Number of Classes.	College.	Year of Graduating.	Number in Class.	Per Cent. Married.	Number of Surviving Children. To Each Married Graduate.	To Each Member of Class Married and Single.	To Class of 200.
1	Princeton ...	'76	118	80.4	2.7	**2.3**	**460**
1	Brown	'72	53	88.7	2.26	**2.—**	**400**
10	Yale..........	'60–'79	1,105	78.4	2.28	**1.79**	**358**
1	Yale..........	'79	118	81.3	2.05	**1.66**	**332**
1	Yale..........	'73	113	82.3	1.98	**1.57**	**314**
2	Bowdoin.....	'75 and '77	107	86.9	1.88	**1.56**	**312**
9	Harvard	'72–'80	1,401	71.4	1.86	**1.34**	**268**
25		'70–'80	3,015	75.7	2.1	**1.49**	**350**
	Yale, Princeton, Brown and Bowdoin.						
16	Y. P. Br. Bo.	'60–'80	1,614	79.4	2.28	**1.81**	**362**
9	Harvard	'72–'80	1,401	71.4	1.86	**1.34**	**268**

This table is arranged according to rate of reproduction.

In view of the data here presented the college graduate does more towards reproducing the population than does the native American of other classes—this is true even of Bowdoin alumni but not of those of Harvard with a lower marriage rate.

I am well aware that this statement must cause surprise. It is contrary to all tradition, but in harmony with the conditions known to exist in all countries of the old world where recent statistical study has enabled us to make such comparisons.

Résumé.—The data now available indicate that the highly educated male element does more towards reproducing itself than any other large group of our native population. The marriage rate is the same, and the number of surviving children to the family is greater than it is for the native population at large, so that we can no longer accuse the college graduate or, if I may say, 'the highly educated male portion of our population,' of having an exceptionally small family, and of doing less than other groups towards reproducing the population; nor must we lay the blame for the low fecundity of the native American family on higher education. Shortening the term of college study will effect no change. Wealth, luxury and social ambition are cause of the diminishing size of the family and of race decline. The factors are the same which have been active in earlier civilizations as they are to-day: increasing wealth and the introduction of foreign manners are pointed out as causing in ancient Rome the lessening fertility among the better classes which preceded political disruption. Cause and effect were the same and even the methods employed to thwart the tendencies of nature were the same: "Few children are born in the gilded bed, to the wealthy dame, so many artifices has she, and so many drugs, to render women sterile and destroy life within the womb" (Juvenal Sat. VI., ll. 594).

The assumption of a false social position, the struggle for the attainment of luxury even more than its possession, leads to the limitation of the family, by 'the increased amount of restraint exercised,' as one author delicately expresses it, but to speak without circumlocution, by often ruinous measures for the prevention of conception, and by criminal means for the destruction of the product of such conception if it does accidentally occur. Such, in plain words, are the causes which lead to the small size of the American family of all classes.

DISCUSSION AND CORRESPONDENCE.

MAGAZINE SCIENCE.

To the Editor: In the course of the past year or two I have read quite a number of articles on scientific subjects in different magazines by Carl Snyder. They seem very interesting, and I should like to know whether they are quite reliable.—B. F. L.

[This question, which in one form or another has been asked a number of times, must be answered in the negative. Mr. Snyder appears not to have had a scientific training; his articles are sensational and inaccurate. This somewhat sweeping condemnation is easily justified. Let us consider the last article by Mr. Snyder that has come to our attention—'The Mechanism of the Brain' in *Harper's Monthly* for May. It is a potpourri of truth, half-truth and falsehood concerning chemistry, physics, anatomy, physiology and psychology. Thus we are told:

> Or, supposing that this especial colloid cannot be fixed upon as the seat of the highest powers of man, they might be thrown upon that extraordinary and rather hypothetical ether, of which physicists talk so much and know so little.

Within half a column Mr. Snyder passes easily from the ether to electricity:

> As there is no nerve action without the evident presence of electricity, it seems probable that nerve action, thought, and consciousness, and what in our present ignorance we call electricity, are one and the same

Physicists may not know all that they would like to know about the ether and electricity, but they know enough not to write nonsense about them.

As an example of misstatement of fact the following may be quoted:

> The size of the brains of comparatively few distinguished men is known, and most published figures are worthless. The list given below is authoritative, and speaks for itself. . . . It will be seen that Byron, who was commonly supposed to have a small head, is highest in the list; and whatever may be thought of his poetry, certainly he was a man of rather mediocre intellectual attainments, as poets generally are.

The question of the intellectual attainments of poets may be left to the editor of *Harper's Monthly;* we are able to state definitely that the weight of Byron's brain is unknown, as is also true in the case of Turgenieff, whose brain is given as the second largest on Mr. Snyder's 'authoritative' list. In the same paragraph Mr. Snyder says:

> Directions for measuring the size of your own brain, if you are interested, will be found in any good encyclopædia, or would doubtless be supplied by the distinguished Professor Wilder of Cornell.

Apart from such indications as are given by the size of the hat, the only feasible directions would be for the interested person to commit suicide, bequeathing his brain to Professor Wilder's collection.

It may seem unkind thus to criticize Mr. Snyder's articles, but it is unfair to the public for magazines, such as *Harper's, Scribner's, The Century* and *McClure's*, not to separate their science from their fiction.—EDITOR.]

SCIENTIFIC LITERATURE.

HERMANN VON HELMHOLTZ.

Hermann von Helmholtz, one of the great names in the history of science, is the subject of a sympathetic and dignified biography prepared by Dr. Leo Koenigsberger and published in three volumes by Vieweg. The interests of von Helmholtz were so far-reaching, his activities so multifarious and his intellect so profound that the preparation of an adequate memoir was a task of unusual difficulty. It is fortunate that it has been so adequately performed. Hermann Ludwig

Hermann von Helmholtz.
From a drawing by Lenbach (1894).

Ferdinand von Helmholtz was the son of a gymnasium teacher, his mother, Caroline Penne, being a descendant of William Penn. He was born at Potsdam on August 31, 1821, and died in Berlin on September 8, 1894. After a childhood of ill health, he studied medicine and was for four years a military surgeon; for a year he was teacher in the Berlin Academy of Fine Arts, and afterwards professor of physiology at Königsberg from 1849 to 1855. He was professor at Bonn for three years and was then professor of physiology at Heidelberg from 1858 to 1871, when he was transferred to Berlin as professor of physics. In 1888 he was made president of the Reichsanstalt, organized under his direction. All possible academic and imperial honors were of course conferred on him.

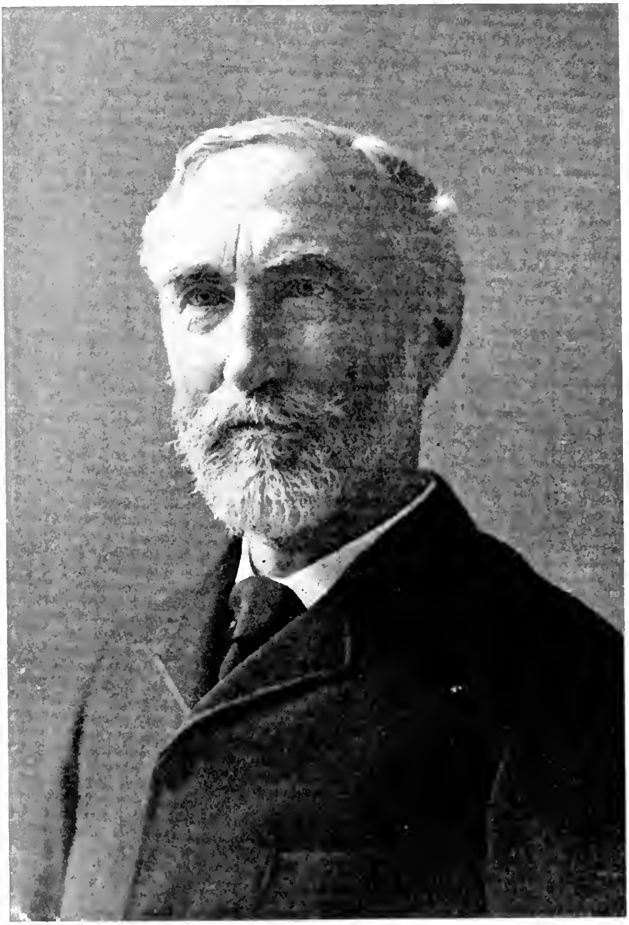
Helmholtz married Olga von Velten in 1849. She died after ten years, and in 1861 he married Anna von Muhl, who died in 1899. One of his sons died in 1889, the other in 1901. His surviving daughter is the wife of Wilhelm von Siemans. Helmholtz traveled more than is the usual habit of the German professor. His visit to America in 1893 will be remembered by many. He seems to have had misgivings in regard to a civilization which has electric lights, while the elements of the art of cookery are 'äusserst Stümperhaft,' and bandits and reporters go at large.

A list of Helmholtz's contributions to science would fill many pages. The essay on the conservation of energy was printed in 1847. Researches of great range and importance, including the invention of the ophthalmoscope, led to his two epoch-making books on physiological psychology—'Tonempfindungen' (1862) and 'Physiologische Optik' (1867). Helmholtz always continued his work in physiological psychology, but his transfer from a chair of physiology to one of physics represented a change in his main interests. His great contributions to mathematical physics, especially electrodynamics, are of almost unparalleled importance.

THE PROGRESS OF SCIENCE.

JOSIAH WILLARD GIBBS.

It is well known that the past quarter of a century has been one of extraordinary advances in the sciences of heat, light, electricity and magnetism. It is less well known, however, that this period has been one of extraordinary losses by death of the eminent mathematical physicists who have contributed to those advances. Maxwell, Kirchhoff, Hertz, Helmholtz, Fitzgerald, Rowland, Stokes, and now Gibbs, have all fallen since 1879. Only two of these leaders, Helmholtz and Stokes, passed the proverbial three score and ten years; Kirchhoff and Gibbs attained only a little more than sixty years; while the others, as if to



J. WILLARD GIBBS.

indicate that it is the pace of hard thinking that kills, all fell at the age of fifty or less.

Josiah Willard Gibbs was born at New Haven, Connecticut, February 11, 1839, and he died at the same place April 28, 1903. He was the son of Josiah Willard Gibbs, professor of sacred literature in Yale College from 1822 to 1861, and Mary Anna (Van Cleve) Gibbs. His preliminary academic studies were pursued at the Hopkins Grammar School, New Haven, and he entered Yale College, at the early age of fifteen years, in 1854. As an undergraduate he easily won distinction, and he took prizes for meritorious work in Latin and in mathematics.

After graduation from Yale College, in 1858, he spent five years there as a student of the mathematico-physical sciences especially. From 1863 to 1866 he served as a tutor at Yale. The next three years he spent in Europe, studying at the universities of Paris, Berlin and Heidelberg. In 1871 he was elected to the professorship of mathematical physics at Yale, and he held this chair up to the time of his death.

Early in his scientific career Professor Gibbs appears to have concentrated attention on the field of thermodynamics, and during the decade following his appointment to a professorship he produced a series of papers which placed him in the front rank of workers in this field. Indeed, the most important of these papers, 'On the Equilibrium of Heterogeneous Substances,' is now regarded as marking an epoch in the history of thermodynamics and as furnishing the foundation for the new science of physical chemistry. The comprehensive knowledge of mechanical philosophy which made him a master in thermodynamics, made him also an authority in electromagnetic science, and during the decade from 1880 to 1890 he published several noteworthy papers on the electromagnetic theory of light and kindred topics. He was likewise a profound student of pure mathematics. His vice-presidential address, 'On Multiple Algebra,' read before the section of astronomy and mathematics of the American Association for the Advancement of Science in 1886, is an original contribution of great merit in a domain already well worked by Möbius, Hamilton, Grassmann, Peirce, Tait and others. His more recent contributions to science are found in two volumes of the Yale Bicentenial Publications, namely, 'Vector Analysis,' edited by a pupil, Dr. E. B. Wilson, and 'Elementary Principles of Statistical Mechanics.' The unpretentious title of the latter work, though strikingly characteristic of the author, is too modest; for it appears destined to take rank among the small number of fundamental contributions to the science of mechanics.

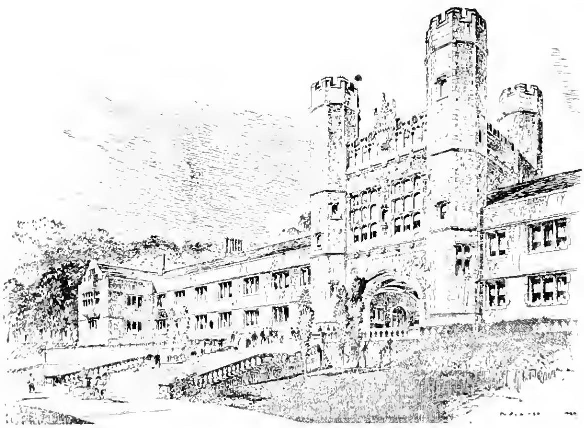
Professor Gibbs was the recipient of many honors from scientific societies at home and abroad. He knew well how to economize his time, however; and although one of the most genial and kindly of men, he mingled sparingly with the world, and was thus, alas! too little known and appreciated, especially by the younger generation of his fellow-countrymen interested in science.

THE SCIENTIFIC PROGRAM OF THE LOUISIANA PURCHASE EXPOSITION.

The dedication of the Louisiana Purchase Exposition on April 30 demonstrated to a hundred thousand visitors that the preparations are unusually far forward. Many of the buildings are practically ready, and the fencing, grading, road-making and the like of the 1,200 acres are well advanced. Indeed, the exposition bids fair to be bigger and more successful than might have been anticipated. Thanks to hitting upon the psychological moment in international relations and of domestic liberality, money is being spent by the tens of millions,

and a world somewhat weary of world fairs is arousing itself to an active interest in the St. Louis Exposition. Of most immediate scientific concern is the Congress of Arts and Sciences, described by Professor Hugo Münsterberg, of Harvard University, in the *Atlantic Monthly* for May.

EDUCATIONAL BUILDING, LOUISIANA PURCHASE EXPOSITION.



UNIVERSITY HALL, WASHINGTON UNIVERSITY, EXECUTIVE BUILDING OF THE LOUISIANA PURCHASE EXPOSITION.

Professor Münsterberg tells us that he proposed to substitute for the congeries of international congresses which have formed a part of recent world fairs a single congress demonstrating the unity of human knowledge, and that his plan has been adopted in all its details. There will doubtless be some protest against the scheme from men of science, as it is difficult to draw the line between demonstrating the unity of knowledge and illustrating the tenets of Professor Münsterberg's system of philosophy. The catalogue of Harvard University or the names of our national scientific societies would give a more objective classification of the sciences.

Professor Münsterberg divides the sciences into seven groups, of which four are theoretical and three practical. The theoretical sciences are normative (philosophy and mathematics), historical (which do not deal with the

description and explanation of phenomena), physical and mental. The practical sciences are utilitarian, regulative and cultural. These seven divisions are subdivided into twenty-five departments and one hundred and thirty sections. The congress is to open on Monday, September 19, when the three members of the organizing committee will make introductory addresses—Professor Newcomb on scientific work, Professor Münsterberg on the unity of theoretical knowledge and Professor Small on the unity of practical knowledge. In the afternoon there are to be addresses in each of the seven divisions on its fundamental conceptions. On the next day there will be two addresses in each of the twenty-five departments, one on its development during the last hundred years, the other on its methods. On the following four days the seventy-one theoretical and the fifty-nine practical sections will each be addressed by two speakers, one treating the relation of the section to other sciences and the other the problems of to-day. The addresses before the divisions and departments are to be made by Americans, and at least one of those before each of the one hundred and thirty sections by foreigners. The authorities of the exposition have made a liberal appropriation—$200,000 it is said—toward the expenses of the congress. The speakers will be paid, and their addresses will be published.

CONGRESSES OF PHYSICIANS.

The Fourteenth International Congress of Medicine met at Madrid during the last week of April; the American Medical Association held its fifty-fourth annual meeting at New Orleans in the first week of May, and the Congress of Physicians and Surgeons held its sixth triennial session at Washington during the following week. The multiplicity of sections, societies, addresses and papers is bewildering and beyond the possibility of brief description.

At Madrid there were some 5,000 delegates, those from foreign nations being proportioned as follows: Germany and Austria, 1,000; France, 825; Great Britain, 235; Russia, 290; Italy, 335; other European countries, 327; United States, 193; South America, 136. The prize for original research, established by the city of Moscow, in honor of the meeting of the congress in that city in 1897, was awarded to Professor Metchnikoff, and that of Paris to Professor Grassi. The next congress will be at Lisbon in 1906. No discoveries of an epoch-making character were presented to the congress, though the programs contained the titles of many papers of importance.

The meeting of the American Medical Association was attended by about 2,000 members. Dr. Frank Billings in his presidential address reviewed the present condition of medical education in the United States. There are in the country 156 medical schools which last year graduated 5,000 physicians. To maintain the present ratio of one physician to 600 of the population, which in the cities, at least, is rather an oversupply, only 3,000 recruits are needed annually. Dr. Billings held that the overcrowding of the medical profession must be controlled by higher standards of education. The American Medical Association has recently organized a house of delegates for the discussion of the interests of the medical profession, and this year a code of ethics was adopted. According to the reports presented, the association is in a flourishing condition. Its membership is over 12,000, having nearly doubled within five years. In this period its funds have increased fourfold, the net increase last year having been $40,000. The prosperity of the association is largely due to its weekly journal, which has a circulation of over 25,000.

The Congress of American Physicians and Surgeons, which meets once

in three years at Washington, is an affiliation of national medical societies devoted chiefly to different departments, but including the Association of American Physicians, which is a small and select body of practitioners. These societies, sixteen in number, had special programs, holding their sessions in the mornings, while the congress met as a whole in the afternoons and evenings. The president, Dr. W. W. Keen, of Philadelphia, chose as the subject of his address 'The Duties and Responsibilities of Trustees of Medical Institutions.' The subjects for special discussion were 'The Pancreas and Pancreatic Diseases' and 'The Medical and Surgical Aspects of the Diseases of the Gall-bladder and Bile Ducts.'

SCIENTIFIC ITEMS.

Paul Belloni Du Chaillu, the explorer and author, died at St. Petersburg on April 29. He was born in New Orleans in 1838, and in 1855 he went from New York to the west coast of Africa, where he made the well-known expedition described in his 'Explorations and Adventures in Equatorial Africa.'

At the recent meeting of the National Academy of Sciences new members were elected as follows: T. C. Chamberlin, professor of geology, University of Chicago; William James, professor of philosophy, Harvard University; E. L. Mark, professor of anatomy, Harvard University; Arthur G. Webster, professor of physics, Clark University; Horace L. Wells, professor of analytical chemistry and metallurgy, Yale University.

The board of regents of the University of Wisconsin on April 21 elected Dr. Charles R. Van Hise, professor of geology, to the presidency of that institution.—The Walker Grand Prize, which is bestowed once in five years by the Boston Society of Natural History, has just been awarded to J. A. Allen of the American Museum of Natural History 'for his able and long continued contributions to American ornithology and mammalogy.—Professor Simon Newcomb, of Washington, has been appointed a delegate from the National Academy of Sciences to the International Association of Academies, which meets in London this coming June. Mr. S. F. Emmons and Mr. Geo. F. Becker, of Washington, and Professor C. R. Van Hise, of Madison, Wis., have been appointed delegates to the International Geological Congress, which meets in Vienna in August of this year.

Mr. Andrew Carnegie has given $1,000,000 for a building for the engineering societies. It is to be situated in New York City, and will provide an auditorium, a library and headquarters for five engineering societies, namely, the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Society of Electrical Engineers, the American Institute of Mining Engineers and the Engineers Club. Mr. Carnegie has also given $1,500,000 for the erection of a court house and library for the permanent court of arbitration at The Hague and $600,000 to the endowment fund of the Tuskegee Normal and Industrial Institute.

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HERTZIAN WAVE WIRELESS TELEGRAPHY. II.

BY DR. J. A. FLEMING, F.R.S.,
PROFESSOR OF ELECTRICAL ENGINEERING, UNIVERSITY COLLEGE, LONDON.

WE have next to consider the appliances for creating the necessary charging electromotive force, and for storing and releasing this charge at pleasure, so as to generate the required electrical oscillations in the aerial.

It is essential that this generator should be able to create not only large potential difference, but also a certain minimum electric current. Accordingly, we are limited at the present moment to one of two appliances, viz., the induction coil or the alternating current transformer.

It will not be necessary to enter into an explanation of the action of the induction coil. The coil generally employed for wireless telegraphy is technically known as a ten-inch coil, *i. e.,* a coil which is capable of giving a ten-inch spark between pointed conductors in air at ordinary pressure. The construction of a large coil of this description is a matter requiring great technical skill, and is not to be attempted without considerable previous experience in the manufacture of smaller coils. The secondary circuit of a ten-inch coil is formed of double silk-covered copper wire, generally speaking the gauge called No. 36, or else No. 34 S.W.G. is used, and a length of ten to seventeen miles of wire is employed on the secondary circuit, according to the gauge of wire selected. For the precautions necessary in constructing the secondary coil, practical manuals must be consulted.*

* Instruction for the manufacture of large induction coils may be obtained from a 'Treatise on the Construction of Large Induction Coils,' by A. T. Hare. (Methuen & Co., London.)

Very great care is required in the insulation of the secondary circuit of an induction coil to be used in Hertzian wave telegraphy, because the secondary circuit is then subjected to impulsive electromotive forces lasting for a short time, having a much higher electromotive force than that which the coil itself normally produces.

The primary circuit of a ten-inch coil generally consists of a length of 300 or 400 feet of thick insulated copper wire. In such a coil the secondary circuit would require about ten miles of No. 34 H.C. copper wire, making 50,000 turns round the core. It would have a resistance at ordinary temperatures of 6,600 ohms, and an inductance of 460 henrys. The primary circuit, if formed of 360 turns of No. 12 H.C. copper wire, would have a resistance of 0.36 of an ohm, and an inductance of 0.02 of a henry.

An important matter in connection with an induction coil to be used for wireless telegraphy is the resistance of the secondary circuit. The purpose for which we employ the coil is to charge a condenser of some kind. If a constant electromotive force (V) is applied to the terminals of a condenser having a capacity C, then the difference of potential (v) of the terminals of the condenser at any time that the contact is made is given by the expression:

$$v = V(1 - e^{-\frac{t}{RC}})$$

In the above equation, the letter e stands for the number 2.71828, the base of the Napierian logarithms, and R is the resistance in series with the condenser, of which the capacity is C, to which the electromotive force is applied. This equation can easily be deduced from first principles,* and it shows that the potential difference v of the terminals of the condenser does not instantly attain a value equal to the impressed electromotive force V, but rises up gradually. Thus, for instance, suppose that a condenser of one microfarad is being charged through a resistance of one megohm by an impressed voltage of 100 volts, the equation shows that at the end of the first second after contact, the terminal potential difference of the condenser will be only 63 volts, at the end of the second second, 86 volts, and so on.

Since e^{-10} is an exceedingly small number, it follows that in ten seconds the condenser would be practically charged with a voltage equal to 100 volts. The product CR in the above equation is called the

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Also see Vol. II. of 'The Alternate Current Transformer,' by J. A. Fleming, Chap. I. (The Electrician Publishing Co., 1, Salisbury Court, Fleet St., London, E. C.)

* See 'The Alternate Current Transformer,' by J. A. Fleming, Vol. I., page 184.

time-constant of the condenser, and we may say that the condenser is practically charged after an interval of time equal to ten times the time-constant, counting from the moment of first contact between the condenser and the source of constant voltage. The time-constant is to be reckoned as the product of the capacity (C) in microfarads, by the resistance of the charging circuit (R) in megohms. To take another illustration. Supposing we are charging a condenser having a capacity of one hundredth of a microfarad, through a resistance of ten thousand ohms. Since ten thousand ohms is equal to one hundredth of a megohm, the time-constant would be equal to one ten-thousandth of a second, and ten times this time-constant would be equal to a thousandth of a second. Hence in order to charge the above capacity through the above resistance, it is necessary that the contact between the source of voltage and the condenser should be maintained for at least one thousandth part of a second.

In discussing the methods of interrupting the circuit, we shall return to this matter, but, meanwhile, it may be said that in order to secure a small time-constant for the charging circuit, it is desirable that the secondary circuit of the induction coil should have as low a resistance as possible. This, of course, involves winding the secondary circuit with a rather thick wire. If, however, we employ a wire larger in size than No. 34, or at the most No. 32, the bulk and the cost of the induction coil began to rise very rapidly. Hence, as in all other departments of electrical construction, the details of the design are more or less a matter of compromise. Generally speaking, however, it may be said that the larger the capacity which is to be charged, the lower should be the resistance of the secondary circuit of the induction coil.

In the practical construction of induction coils for wireless telegraphy, manufacturers have departed from the stock designs. We are all familiar with the appearance of the instrument maker's induction coil; its polished mahogany base, its lacquered brass fittings, and its secondary bobbin constructed of and covered with ebonite. But such a coil, although it may look very pretty on the lecture table, is yet very unsuited to positions in which it may be used in connection with Hertzian wave telegraphy.

Three important adjuncts of the induction coil are the primary condenser, the interrupter and the primary key. The interrupter is the arrangement for intermitting the primary current. We have in some way or other to rapidly interrupt the primary current, and the torrent of sparks that then appears between the secondary terminals of the coil is due to the electromotive force set up in the secondary circuit at each break or interruption of the primary circuit. We may divide interrupters into five classes.

We have first the well known hammer interrupter which continental writers generally attribute to Neef or Wagner.* In this interrupter, the magnetization of the iron core of the coil is caused to attract a soft-iron block fixed at the top of a brass spring, and by so doing to interrupt the primary circuit between two platinum contacts. Mr. Apps, of London, added an arrangement for pressing back the spring against the back contact, and the form of hammer that is now generally employed is therefore called an Apps break.

As the ten-inch coil takes a primary current of ten amperes at sixteen volts when in operation, it requires very substantial platinum contacts to withstand the interruption of this current continuously without damage. The small platinum contacts that are generally put on these coils by instrument makers are very soon worn out in practical wireless telegraph work. If a hammer break is used at all, it is essential to make the contacts of very stout pieces of platinum, and from time to time, as they get burnt away or roughened, they must be smoothed up with a fine file. It does not require much skill to keep the hammer contacts in good order, and prevent them from sticking together and becoming damaged by the break spark.

By regulating the pressure of the spring against the back contact, by means of an adjusting screw, the rate at which the break vibrates can be regulated, but as a rule it is not possible, with a hammer break, to obtain more than about 800 interruptions per minute, or say twelve a second. The hammer break is usually operated by the magnetism of the iron core of the coil, but for some reasons it is better to separate the break from the coil altogether, and to work it by an independent electromagnet, which, however, may be excited by a current from the same battery supplying the induction coil. For coils up to the ten-inch size the hammer break can be used when very rapid interruptions are not required. It is not in general practicable to work coils larger than the ten-inch size with a platinum contact hammer break, as such a butt contact becomes overheated and sticks if more than ten amperes is passed through it. In the case of larger coils, we have to employ some form of interrupter in which mercury or a conducting liquid forms one of the contact surfaces.

The next class of interrupter is the vibrating or hand-worked mercury break, in which a platinum or steel pin is made to vibrate in and out of mercury. This movement may be effected by the attraction of an iron armature by an electromagnet, or by the varying magnetism of the core of the coil, or it may be effected more slowly by hand.

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* Du Moncel states that MacGauley of Dublin independently invented the form of hammer break as now used.

See 'The Alternate Current Transformer,' Vol. II., Chap. I., J. A. Fleming.

The mercury surface must be covered with water, alcohol, paraffin or creosote oil to prevent oxidation and to extinguish the break spark. The interruption of the primary current obtained by the mercury break is more sudden than that obtained by the platinum contact in air, in consequence of the more rapid extinction of the spark; hence the sparks obtained from coils fitted with mercury interrupters are generally from twenty to thirty per cent. longer than those obtained from the same coil under the same conditions, with platinum contact interrupters. The mercury breaks will not, however, work well unless cleaned at regular intervals by emptying off the oil and rinsing well with clean water, and hence they require rather more attention than platinum interrupters. It is not generally possible to obtain so many interruptions per minute with the simple vibrating mercury interrupter as with the ordinary hammer interrupter. The mercury interrupter has, however, the advantage that the contact time during which the circuit is kept closed may be made longer than is the case with the hammer break. Also, if fresh water is allowed to flow continuously over the mercury surface, it can be kept clean, and the break will then operate for considerable periods of time without attention. The mercury interrupter may be worked by a separate electromagnet or by the magnetism of the core of the induction coil.

The third class of interrupter may be called the motor interrupter, of which a large number have been invented in recent years. In this interrupter some form of a continuously rotating electromotor is employed to make and break a mercury or other liquid contact. In one simple form, the motor shaft carries an eccentric, which simply dips a platinum point into mercury, or else a platinum horseshoe into two mercury surfaces, making in this manner an interruption of the primary circuit at one or two places. As a small motor can easily be run at twelve hundred revolutions per minute, or twenty per second, it is possible to secure easily in this manner a uniform rate of interruption of the primary current, at the rate of about twenty per second. If, however, much higher speeds are employed, then the time of contact becomes abbreviated, and the ability of the coil to charge a capacity is diminished.

Professor J. Trowbridge has described an effective form of motor break for large coils, in which the interruption is caused by withdrawing a stout platinum wire from a dilute solution of sulphuric acid, and by this means he increased the spark given by a coil provided with hammer break and condenser from fifteen inches to thirty inches, when using the liquid break and no condenser.*

* See Professor J. Trowbridge, 'On the Induction Coil,' *Phil. Mag.*, April, 1902. Vol. III., Series 6, p. 393.

A good form of motor-interrupter, due to Dr. Mackenzie Davidson, consists of a slate disc bearing pin contacts fixed on the prolonged steel axle of a motor placed in an inclined position; the disc and the lower part of the axle lie in a vessel filled one third with mercury, and two thirds with paraffin oil. The circuit is made and broken by the revolution of the disc causing the pins to enter and leave the mercury. The speed of the motor can be regulated by a small resistance, and can be adapted to the electromotive force used in the primary circuit. When the motor is running slowly, the interrupter can be used with a low electromotive force, that is to say, something between twelve and twenty volts, but with a higher speed a large electromotive force can be used without danger of overheating the primary coil, and with an electromotive force of about fifty volts, the interruptions may be so rapid that an unbroken arc of flame, resembling an alternating current arc, springs between the secondary terminals of the coil.

Mr. Tesla has devised numerous forms of rotating mercury break. In one, a star-shaped metal disc revolves in a box so that its points dip into mercury covered with oil, and make and break contact. In another form, a jet of mercury plays against a similar shaped rotating wheel. For details, the reader must consult the fuller descriptions in *The Electrical World* of New York, Vol. XXXII.. p. 111, 1898; also Vol. XXXIII., p. 247; or *Science Abstracts,* Vol. II., pp. 46 and 457, 1898.

The fourth class of interrupter is called a turbine interrupter. In this appliance, a jet of mercury is forced out of a small aperture by means of a centrifugal pump, and is made to squirt against a metal plate, and interrupted intermittently by a toothed wheel made of insulating material rotated by the motor which drives the pump. The current supplying the coil passes through or along this jet of mercury, and is therefore rendered intermittent when the wheel revolves. In the case of this interrupter, the duration of the contacts, as well as the number of interruptions per second, is under control, and for this reason better results are probably obtained with it than with any other form of break.

A description of a turbine mercury break devised by M. Max Levy was given in the *Elektrotechnische Zeitschrift,* Vol. XX., p. 717, October 12, 1899 (see also *Science Abstracts,* Vol. III., p. 63, abstract No. 165) as follows:

A toothed wheel made of insulating material carries from 6 to 24 teeth, and can be made to rotate from 300 to 1,000 times per minute, the interruptions being thus regulated between 5 and 400 per second. By raising or lowering the position of the jet of mercury and that of the plate against which it strikes, the duration of the contact can be

varied, so that it is possible to regulate this period without disturbing the number of interruptions per second.

The sparks obtained from a coil worked with a turbine interrupter have more quantity than the sparks obtained with any other interrupter under similar conditions, and the coil can be worked with a far higher voltage than is possible when using the hammer break. In this manner, the appearance of the secondary sparks can be varied from the thin snappy sparks given by the hammer break to the thick flame-like arc sparks given by the electrolytic break. This break can be adapted for any voltage from twelve to two hundred and fifty volts, and the primary circuit can not be closed before the interrupter is acting. The mercury in the break is generally covered with alcohol or paraffin oil to reduce oxidation, and the appliance is nearly noiseless when in operation. The mercury has to be cleaned at intervals, if the interrupter is much used. If alcohol is used to cover the mercury, the cleaning is very simple; the break requires only to be rinsed under a water tap. When paraffin oil is used, the cleaning is generally effected with the help of a few ounces of sulphuric acid in a very few minutes. It is best, however, to clean the mercury continuously by allowing the water to flow over it.

The motor driving the centrifugal pump and the fan can be wound for any voltage, and it is best to have it so arranged that this motor works on the same battery which supplies the primary circuit of the coil, the two circuits working parallel together. A rheostat can be added to the motor circuit to regulate the speed.

The turbine break driven by an independent motor, which is kept always running, has another advantage over the hammer break in practical wireless telegraphy, viz., that a useful secondary spark can be secured with a shorter time of closure of the primary circuit, since there is no inertia to overcome as in the case of the hammer break. This latter form has only continued in use because of its simplicity and ease of management by ordinary operators.

The mercury turbine interrupter has been extensively adopted both in the German and British navies in connection with induction coils used for wireless telegraphy.

Lastly we have the electrolytic interrupters, the first of which was introduced by Dr. Wehnelt, of Charlottenburg, in the year 1899, and modified by subsequent inventors. In its original form, a glass vessel filled with dilute sulphuric acid (one of acid to five or else ten parts of water) contains two electrodes of very different sizes; one is a large lead electrode formed of a piece of sheet lead laid round the interior of the vessel, and the other is a short piece of platinum wire projecting from the end of a glass or porcelain tube. The smaller of these elec-

trodes is made the positive, and the large one the negative. If this electrolytic cell is connected in series with the primary circuit of the induction coil (the condenser being cut out) and supplied with an electromotive force from forty to eighty volts, an electrolytic action takes place which interrupts the current periodically.* An enormous number of interruptions can, by suitable adjustment, be produced per second, and the appearance of a discharge from the secondary terminals of the coil, while using the Wehnelt break, more resembles an alternate current arc than the usual disruptive spark.

At the time when the Wehnelt break was first introduced, great interest was excited in it, and the technical journals in 1899 were full of discussions as to the theory of its operation.† The general facts concerning the Wehnelt break are that the electrolyte must be dilute sulphuric acid in the proportion of one of acid to five or ten of water. The large lead plate must be the cathode or negative pole, and the anode or positive pole must be a platinum wire, about a millimeter in diameter, and projecting one or two millimeters from the pointed end of a porcelain, glass or other acid-proof insulating tube. The aperture through which the platinum wire works must be so tight that acid can not enter, yet it is desirable that the platinum wire should be capable of being projected more or less from the aperture by means of an adjusting screw. The glass vessel which contains these two electrodes should be of considerable size, holding say a quart of fluid, and it is better to include this vessel in a larger one in which water can be placed to cool the electrolyte, as the latter gets very warm when the break is used continuously. If such an electrolytic cell has a continuous electromotive force applied to it tending to force a current through the electrolyte from the platinum wire to the lead plate, we can distinguish three stages in its operation, which are determined by the electromotive force and the inductance in the circuit. First, if the electromotive force is below sixteen or twenty volts, then ordinary and silent electrolysis of the liquid proceeds, bubbles of oxygen being liberated from the platinum wire and hydrogen set free against the lead plate. If the electromotive force is raised above twenty-five volts, then if there is no inductance in the circuit, the continuous flow of current proceeds, but if the circuit of the electrolyte possesses a certain

* See Dr. Wehnelt's article in the *Elektrotechnische Zeitschrift*, January, 1899.

† See *Electrician*, Vol. XLII., 1899, pp. 721, 728, 731, 732 and 841. Communications from Mr. Campbell Swinton, Professor S. P. Thompson, Dr. Marchant, the author and others. Also page 864, same volume, for a leader on the subject. Also page 870, letters by M. Blondel and Professor E. Thomson. See also *Electrician*, Vol. XLIII., p. 5, 1899, extracts from a paper by P. Barry; *Comptes Rendus*, April, 1899. See also *The Electrical Review*, Vol. XLIV., p. 235, 1899, February 17.

minimum inductance, the character of the current flow changes, and it becomes intermittent, and the cell acts as an interrupter, the current being interrupted from 100 to 2,000 times per second, according to the electromotive force, and the inductance of the circuit. Under these conditions, the cell produces a rattling noise and a luminous glow appears round the tip of the platinum wire. Thus, in a particular case, with an inductance of 0.004 millihenry in the circuit of a Wehnelt break, no interruption of the circuit took place, but with one millihenry of inductance in the circuit, and with an electromotive force of 48 volts, the current became intermittent at the rate of 930 per second, and by increasing the voltage to 120 volts, the intermittency rose to 1,850 a second.

The Wehnelt break acts best as an interrupter with an electromotive force from 40 to 80 volts. At higher voltages a third stage sets in: the luminous glow round the platinum wire disappears, and it becomes surrounded with a layer of vapor, as observed by MM. Violle and Chassagny; the interruptions of current cease, and the platinum wire becomes red hot. If there is no inductance in the circuit, the interrupter stage never sets in at all, but the first stage passes directly into the third stage. In the first stage bubbles of oxygen rise steadily from the platinum wire, and in the interrupted stage they rise at longer intervals, but regularly. The cell will not, however, act as a break at all unless some inductance exists in the circuit.

In applying the Wehnelt break to an induction coil, the condenser is discarded and also the ordinary hammer break, and the Wehnelt break is placed in circuit with the primary coil. In some cases, the inductance of the primary coil alone is sufficient to start the break in operation, but with voltages above 50 or 60, it is generally necessary to supplement the inductance of the primary coil by another inductive coil. The best form of Wehnelt break for operating induction coils is the one with multiple anodes (see Dr. Marchant, *The Electrician,* Vol. XLII, page 841, 1899), and when it has to be used for long periods, the kathode may advantageously be formed of a spiral of lead pipe, through which cold water is made to circulate.

Another form of electrolytic break was introduced by Mr. Caldwell. In this, a vessel containing dilute sulphuric acid is divided into two parts. In the partition is a small hole, and in the two compartments are electrodes of sheet lead. The small hole causes an intermittency in the current which converts the arrangement into a break. Mr. Campbell Swinton modified the above arrangement by making the partition to consist of a sort of porcelain test-tube with a hole in the bottom. This hole can be more or less plugged up by a glass rod drawn out to a point, and this is used to more or less close the hole. This porcelain vessel contains dilute acid and stands in a

larger vessel of acid, and lead electrodes are placed in both compartments. The current and intermittency can be regulated by more or less closing the aperture between the two regions.

When the Wehnelt break is applied to an ordinary ten-inch induction coil, and the inductance of the primary circuit and the electromotive force varied until the break interrupts the current regularly, and with the frequency of some hundred a second, the character of the secondary discharge is entirely different from its appearance with the ordinary hammer break. The thin blue lightning-like sparks are then replaced by a thicker mobile flaming discharge, which resembles an alternating current arc, and when carefully examined or photographed is found to consist of a number of separate discharges superimposed upon one another in slightly different positions.

Many theories have been adopted as to the action of the break, but time will not permit us to examine these. Professor S. P. Thompson and Dr. Marchant have suggested a theory of resonance.* One difficulty in explaining the action of the break is created by the fact that it will not work if the platinum wire is made a kathode.

Although the Wehnelt break has some advantages in connection with the use of the induction coil for Röntgen ray work, its utility as far as regards Hertzian wave telegraphy is not by any means so marked. It has already been explained that, in order to charge a condenser of a given capacity at a constant voltage, the electromotive force must be applied for a certain minimum time, which is determined by the value of the capacity and the resistance of the secondary circuit of the induction coil. If the coil is a ten-inch coil and has a secondary resistance of say 6,000 ohms, and if the capacity to be charged has a value say of one thirtieth of a microfarad, then the time-constant of the circuit is 1/5,000 of a second. Therefore, the contact with the condenser must be maintained for at least 1/500 of a second, during the time that the secondary electromotive force of the coil is at its maximum, so that the condenser may become charged to a voltage which the coil is then capable of producing.

In the induction coil, the electromotive force generated in the secondary coil at the 'break' of the primary current is higher than that at the 'make,' and this electromotive force, other things being equal, depends upon the rate at which the magnetism of the iron core dies away, and its duration is shorter in proportion as the whole time occupied in the disappearance of the magnetism is less. The Wehnelt break does not increase the actual secondary electromotive force, nor apparently its duration, but it greatly increases the number of times per second this electromotive force makes its appearance. Hence this break increases the current, but not the electromotive force in the

* See *The Electrician*, Vol. XLII., 1899.

secondary coil. It therefore does not assist us in the direction required, viz., in prolonging the duration of the secondary electromotive force to enable larger capacities to be charged.

The important point in connection with the working of a coil used for charging a condenser is not the length of spark which the coil can give alone, but the length of spark which can be obtained between small balls attached to the secondary terminals, when these terminals are also connected to the two surfaces of the condenser. Thus, a coil may give a ten-inch spark if worked alone, but on a capacity of one thirtieth of a microfarad it may not be able to give more than a five-millimeter spark. Hence in describing the value of a coil for wireless telegraph purposes, it is not the least use to state the length of spark which the coil will give between the pointed conductors in air, but we must know the spark length which it will give between brass balls, say 1 cm. in diameter, connected to the secondary terminals, when these terminals are also short-circuited by a stated capacity, the spark not exceeding that length at which it becomes non-oscillatory.

A good way of describing the value of an induction coil for wireless telegraph purposes is to state the length of oscillatory spark which can be produced between balls one centimeter in diameter connected to the secondary terminals, when these balls are short-circuited by a condenser having a capacity say of one hundredth of a microfarad, and also one tenth of a microfarad.

If a hammer or motor interrupter is employed with the coil, then a primary condenser must be connected across the points between which the primary circuit is broken. This condenser generally consists of sheets of tin-foil alternated with sheets of paraffin paper, and for a ten-inch coil, may have a capacity of about 0.4 or 0.5 of a microfarad.*

Lord Rayleigh discovered that if the interruption of the primary circuit is sufficiently sudden and complete, as when the primary circuit is severed by a bullet from a gun, the primary condenser can be removed and yet the sparks obtained from the secondary circuit are actually longer than those obtained with the condenser and the ordinary break.†

In the use, however, of the coil for Hertzian wave telegraphy, with all interrupters except the Wehnelt break, a condenser of suitable capacity must be joined across the break points.

Turning in the next place to the primary key, or signaling interrupter, it is necessary to be able to control the torrent of sparks between

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* For a discussion of the function of the condenser in an ordinary induction coil, see 'The Alternate Current Transformer,' by J. A. Fleming, Vol. II., p. 51.

† See Lord Rayleigh, *Phil. Mag.*, December, 1901.

the secondary terminals of the coil, and to cut them up into long and short periods in accordance with the letters of the Morse alphabet. This is done by means of the primary key. The primary key generally consists of an ordinary massive single contact key with heavy platinum contacts. As the current to be interrupted amounts to about ten amperes and is flowing in a highly inductive circuit, the spark at break is considerable. If the attempt is made to extinguish this spark by making the contacts move rapidly away from one another through a long distance, in other words, by using a key with a wide movement, then the speed at which the signals can be sent is greatly diminished. The speed of sending greatly depends upon the time taken to move the key up and down between sending two dots, and hence a short range key sends quicker than a long range key. If it is desired to use a short range key, then some method must be employed to extinguish the spark at the contacts. This is done in one of three ways: Either by using a high resistance coil to short-circuit these contacts, or by a condenser, or by a magnetic blow-out, as in the case of an electric tram-car circuit controller. Of these, the magnetic blow-out is probably the best.

Mr. Marconi has designed a signaling key which performs the function not only of interrupting the primary circuit, but at the same time breaks connection between the receiving appliance and the aerial.

The author has designed for signaling purposes a multiple contact key which interrupts the circuit simultaneously in ten or twelve different places. The particular point about this break is the means which are taken to make the twelve interruptions absolutely simultaneous. If these interruptions are not simultaneous, the spark always takes place at the contact which is broken first, but if the circuit is interrupted in a dozen places quite simultaneously, then the spark is cut up into a dozen different portions, and the spark at each contact is very much diminished. By this break, voltages up to two thousand volts may be quite easily dealt with.

Various forms of break have been devised in which the circuit is broken under oil or insulating fluids, but, generally speaking, these devices are not very portable, and a dry contact between platinum surfaces with appropriate means for cutting up the spark and blowing it out so that the mechanical movement of the switch may be small is the best thing to use.

The signaling key is really a very important part of the transmitting arrangement, because whatever may be the improvements in receiving instruments, it is not possible to receive faster than we can send. A great many statements have appeared in the daily papers as to the possibility of receiving hundreds of words a minute by

Hertzian wave telegraphy, but the fact remains that whatever may be the sensibility of the receiving appliance, the rate at which telegraphy of any kind can be conducted is essentially dependent upon the rate at which the signals can be sent, and this in turn is largely dependent upon the mechanical movement which the key has to make to interrupt the primary circuit, and so interrupt the secondary discharge.

In order to make the separation of the contact points of the switch as small as possible, and yet prevent an arc being established, various blow-out devices have been employed. The simplest arrangement for this purpose is a powerful permanent magnet so placed that its interpolar field embraces the contact points and is at right angles to them.

As already explained, the applicability of the induction coil in wireless telegraphy is limited by the fact of the high resistance of the secondary circuit, and the small current that can be supplied from it. Data are yet wanting to show what is the precise efficiency of the induction coil, as used in Hertzian wave telegraphy, but there are reasons for believing that it does not exceed 50 or 60 per cent.

Where large condensers have to be charged, in other words, where we have to deal with larger powers, we are obliged to discard the induction coil and to employ the alternating current transformer. But this introduces us to a new class of difficulties. If an alternating current transformer wound for a secondary voltage, say of 20,000 or 30,000 volts, has its primary circuit connected to an alternator, then if the secondary terminals, to which are connected two spark balls, are gradually brought within striking distance of one another, the moment we do this an alternating current arc starts between these balls. If the transformer is a small one, there is no difficulty in extinguishing this arc by withdrawing the secondary terminals, but if the transformer is a large one, say of ten or twenty kilowatts, dangerous effects are apt to ensue when such an experiment is tried. The short circuiting of the secondary circuit almost entirely annuls the inductance of the primary circuit. There is, therefore, a rush of current into the transformer, and if it is connected to an alternator of low armature resistance, the fuses are generally blown, and other damage done.

Let us suppose then that the secondary terminals of the transformer are also connected to a condenser. On bringing together the spark balls connected with the secondary terminals, we may have one or more oscillatory discharges, but the process will not be continuous, because the moment that the alternating current arc starts between the spark balls, it reduces their difference of potential to a comparatively low value, and hence the charge taken by the condenser is very small, and, moreover, the circuit is not interrupted periodically so as to re-start a train of oscillations.

When, therefore, we desire to employ an alternating current trans-

former as a source of electromotive force, although it may have the advantage that the resistance of the secondary circuit of the transformer is generally small compared with that of the secondary circuit of an induction coil, yet nevertheless we are confronted with two practical difficulties: (1) How to control the primary current flowing into the transformer; and (2) how to destroy the alternating current arc between the spark balls and reduce the discharge entirely to the disruptive or oscillatory discharge of the condenser.

The control over the current can be obtained, in accordance with a plan suggested by the author, by inserting in the primary circuit of the transformer two variable choking coils. The form in which it is preferred to construct these is that of a cylindrical bobbin standing upon a laminated cross-piece of iron. These bobbins can have let down into them an E-shaped piece of laminated iron, so as to complete the magnetic circuit, and thus raise the inductance of the bobbin. By placing two of these variable choking coils in series with the primary circuit, the current is under perfect control. We can fix a minimum value below which the current shall not fall, by adjusting the position of the cores of these two choking coils, and we can then cause that current to be increased up to a certain limit which it can not exceed, by short-circuiting one of these choking coils by an appropriate switch. Several ways have been suggested for extinguishing the alternating current arc which forms between the spark balls connected to the secondary terminals when these are brought within a certain distance of one another. One of these is due to Mr. Tesla. He places a strong electromagnet so that its lines of magnetic flux pass transversely between the spark balls. When the discharge takes place the electric arc is blown out, but if the balls are short-circuited by a condenser, the oscillatory discharge of the condenser still takes place across the spark gap. Professor Elihu Thomson achieves the same result by employing a blast of air thrown on the spark gap. This has the effect of destroying the alternating current arc, but still leaves the oscillating discharge of the condenser. The action is somewhat tedious to explain in words, but it can easily be understood that the blast of air, by continually breaking down the alternating current arc which tends to form, allows the condenser connected to the spark balls to become charged with the potential of the secondary circuit of the transformer, and that this condenser then discharges across the spark gap, producing an oscillatory discharge in the usual manner. The author has found that without the use of any air blast or electromagnet, simple adjustment of the double choking coil in the primary circuit of the transformer as above described is sufficient to bring about the desired result, when the capacity of the condenser is adjusted to be in resonance.

Another method which has been adopted by M. d'Arsonval is to cause the spark to pass between two balls placed at the extremities of metal rods, which are in rapid rotation like the spokes of a wheel. In this case, the draught of air produced by the passage of the spark balls blows out the arc and performs the same function as the blast of air in Professor Elihu Thomson's method. When these adjustments are properly made, it is possible, by means of a condenser and an alternating current transformer supplied with current from an alternator, to create a rapidly intermittent oscillatory discharge, the sparks of which succeed one another so quickly that it appears almost continuous. When using a large transformer and condenser, the noise and brilliancy of these sparks are almost unbearable, and the eyes may be injured by looking at this spark for more than a moment. In the construction of transformers intended to be used in this manner, very special precautions have to be taken in the insulation of the primary and secondary circuits, and the insulation of these from the core.

It may be remarked in passing that experimenting with large high tension transformers coupled to condensers of large capacity is exceedingly dangerous work, and the greatest precautions are necessary to avoid accident. In the light, however, of sufficient experience there is no difficulty in employing high tension transformers in the above described manner, and in obtaining electromotive forces of upwards of a hundred thousand volts supplied through transformers capable of yielding any required amount of current.

On occasions where continuous current alone is available, a motor generator has to be employed converting the continuous current into an alternating current. This is best achieved by the employment of a small alternator directly coupled to a continuous current motor; or by providing the shaft of a continuous current motor with two rings connected to two opposite portions of its armature, so that when continuous current is supplied to the brushes pressing against the commutator, an alternating current can be drawn off from two other brushes touching the above mentioned insulated rings.

The next element of importance in the transmitting arrangement is the spark gap. In the case of those transmitters employing an ordinary induction coil, the secondary spark, or the discharge of any condenser connected to the secondary terminals can be taken between the brass balls about half an inch or one inch in diameter, with which the terminals of the secondary coil are usually furnished; and it is generally the custom to allow this spark discharge to take place in air at ordinary pressure. In the very early days of his work Mr. Marconi adopted the discharger devised by Professor Rhigi, in which the spark takes place between two brass balls placed in vaseline or other highly

insulating oil.* But whatever advantage may accrue from using oil as the dielectric in which the spark discharge takes place, when carrying out simple laboratory experiments on Hertzian waves, there is no advantage in the case of wireless telegraphy. The Rhigi discharger was, therefore, soon discarded. If discharges having large quantity are passed through oil, it is rapidly decomposed or charred, and ceases to retain the special insulating and self-restoring character which is necessary in the medium in which an oscillating spark is formed. The conditions when the discharges of large condensers are passed between spark balls are entirely different from those when the quantity of the spark, or to put it in more exact language, the current passing, is very small. In the case of Hertzian experiments, it is necessary, as shown by Hertz, to maintain a high state of polish on the spark balls when they are employed for the production of short waves of small energy, but when we are dealing with large quantities of energy at each discharge, those methods which succeed for laboratory experiments are perfectly impracticable. The conditions necessary to be fulfilled by a discharger for use in Hertzian wave telegraphy are that the surfaces shall maintain a constant condition and not be fused or eaten away by the spark, and, next, that the medium in which the discharge takes place shall not be decomposed by the passage of the spark, but shall maintain the property of giving way suddenly when a certain critical pressure is reached, and passing instantly from a condition in which it is a very perfect insulator to one in which it is a very good conductor; and, thirdly, that on the cessation of the discharge, the medium shall immediately restore itself to its original condition.

When using the ordinary ten-inch induction coil, and when the capacity charged by it does not exceed a small faction of a microfarad, it is quite sufficient to employ brass or steel balls separated by a certain distance in air, at the ordinary pressure, as the arrangement of the discharger. When, however, we come to deal with the discharges of very large condensers, at high electromotive forces, then it is necessary to have special arrangements to prevent the destruction of the surfaces between which the spark passes, or their continual alteration, and many devices have been invented for this purpose. The author has devised an arrangement which fulfils the above conditions very perfectly for use in large power stations, but the details of this can not be made public at the present time.

* It has sometimes been stated that the spark balls must be *solid* metal and not hollow, but this is a fallacy, and has been disproved by Mr. C. A. Chant. See 'An Experimental Investigation into the Skin Effect in Electrical Oscillators,' *Phil. Mag.*, Vol. III., Sec. 6, p. 425, 1902.

(*To be continued.*)

WHY A FLAME EMITS LIGHT—THE DEVELOPMENT OF THE THEORY.

By Professor ROBERT MONTGOMERY BIRD, Ph.D.,

UNIVERSITY OF THE STATE OF MISSOURI.

As one would naturally suppose, the theory now generally held regarding the nature of an ordinary flame and its power to emit light is not altogether the result of modern research, but one which has been evolved from very ancient and hazy notions. Naught else is to be expected when we consider the important place fire has held throughout the development of mankind. It is the first recorded object of his worship, and we have reason to believe that all architecture had its beginning in rude structures erected to protect the sacred fire. It is not the nature of man to see phenomena so striking as those which attend the consumption of matter by fire and not speculate upon them. But the centuries had multiplied and modern times had been reached before man's ideas regarding fire, flame and light became distinct, and the use of these terms differentiated. The best text-books and works on natural philosophy published near the end of the eighteenth century still used the terms with great looseness, and the conceptions of the material nature of flame and light were yet in their death struggles.

After the corpuscular theory of light had given place to the wave theory, conflicting ideas arose as to why and how a flame emits light waves. When it was agreed that the waves were sent out by solid particles of carbon heated to incandescence, the question of the origin of the carbon, or the chemical changes taking place in the flame, was discussed, and along with this the source of heat which renders it incandescent. The last and most generally accepted answer to these two questions—the origin of carbon particles and the source of heat—is given in the 'acetylene theory,' first advanced in 1892 by Professor Vivian B. Lewes, of England.

This theory expressed briefly is that a portion of the hydrocarbon gas, by the heat of combustion of another portion, is converted into acetylene, and that this on being decomposed by heat furnishes the carbon particles, which particles are rendered incandescent mainly by the heat liberated when the gas is decomposed; acetylene being a substance which absorbs heat during its formation and hence liberates heat when it breaks down. Whatever is burned, whether a solid candle or liquid oil, must pass through the gaseous state, and hence this applies to all flames used for lighting purposes.

But before explaining this theory more fully and seeing upon what experimental evidence it is based, it would be well to consider its genesis and briefly recall the ancient notions regarding 'artificial' light.

Light was first confused with seeing, and it is said that up to the time of Aristotle men commonly thought they saw by reason of something shooting out from the eyes and coming in contact with objects; the converse of the Cartesian conception of many centuries later, that certain movements in bodies cause them to shoot out minute particles in all directions, which, striking the eye or causing 'globules' of air to strike it, excite vision.

The fluid nature of fire and the corporeal nature of light, which were believed in throughout the early and middle ages, seem to have been first doubted by Sir Francis Bacon about the end of the sixteenth century, although he was by no means sure that these conceptions were wrong. Bacon classed together the light from flames, decayed wood, glowworms, silks, polished surfaces, etc., and said that inasmuch as some animals can see in the dark, air has some light of itself. Boerhaave, somewhat later, also expressed doubts as to the substantive nature of fire.

Among the first recorded experiments upon the nature and action of luminous flames are those which were carried out by Sir Robert Boyle between 1660 and 1670. He attempted to prove by experiment whether the light from a flame is like that from the sun, and whether it is corporeal or merely a quality. He allowed a flame to play on metals directly and also when in open and sealed vessels, and because the substance formed a calx and gained in weight, he thought that the light or flame (he uses the terms indiscriminately) had combined with the metal, and hence it must be a fluid. Boyle also conducted a large number of experiments upon live or 'quick' coals, phosphorescent bodies, animals and insects to see the effect of exhausting a receiver in which they were placed, and he seems to have concluded that the lights from live coals, rotten wood and putrefying fish differ not in kind but only in degree. He considered that the increase of light from coals, etc., and the reviving of certain insects when air was readmitted to the receiver indicated a relation between a visible flame and the so-called 'vital flame.' But he would not commit himself upon the question of the supposed kinship between the 'flame' from live coals and rotten wood and the 'vital flame' thought to be burning in the hearts of all living beings.

The interesting views of Sir Isaac Newton are set forth in a number of queries published in his work entitled 'Optics.' As is well known, Newton believed in the material nature of light, and he asserted that the change of light into matter and of matter into light is an acknowledged possibility and of common occurrence. He attributed the light

which appears when a body is rapidly and repeatedly struck or when heated beyond a certain point, as when flint and steel are struck together, etc., to vibrations of the parts of the body so rapid as to throw off the particles which, according to Newton's idea, occasion the sensation of light. With these he also classed electric sparks, saying that the 'electric vapor' excited by rubbing glass dashes against a strip of paper or the end of the finger held to it, is thereby so agitated as to cause it to emit light. He thought the light from glowworms and putrefying matter was of the same kind as the above, and said that the light seen at night in the eyes of certain animals, cats for instance, is 'due to vital motions.'

Regarding true luminous flames Newton's ideas were nearer those of the present time. He wrote "Is not fire a body heated so hot as to emit light copiously? For what else is a red hot iron than fire? And what else is a burning coal than red hot wood?" "Is not flame a vapor, fume or exhalation heated red hot, that is, so hot as to shine? For bodies do not flame without emitting a copious fume, and this fume burns in the flame. Metals in fusion do not flame for want of a copious fume." "All fuming bodies, as oil, tallow, wax, wood, etc., by fuming waste and vanish into burning smoke." 'Put out the flame and the smoke is visible, it often smells; and the nature of the smoke determines the color of the flame.' "Smoke passing through flame can not but grow red hot, and red hot smoke can have no other appearance than that of flame."

During the hundred years, more or less, following the publication of Newton's views there was little change in the prevailing theories. Stahl said 'flame is light' liberated from bodies in the act of combustion, and that light and heat are the constant attendants of fire; fire combined with combustible matter was 'phlogiston.' Scheele said light, heat and fire are combinations of air and 'phlogiston.' Lavoisier thought flame to be light disengaged from air, with which it had been in combination, and this idea seems to have been adopted by most of the French chemists.

There might be mentioned in this connection the queer ideas regarding our being able to see objects, and the emission of light by incombustible bodies, which were held during the latter half of the eighteenth century. As expressed by Macquer, and quoted by Fourcroy,* "The vibrations (under the impulse of more or less heat) dispose the particles (of bodies) in such a manner that their faces, acting like so many little mirrors, reflect upon our eyes the rays of light which are in the air by night as well as by day; for we are involved in darkness during the night for no other reason but because they are not then so directed as to face our organs of sight."

* Fourcroy's 'Chemistry,' press date 1796.

At a single step we pass from the rather crude ideas of the older thinkers to those ideas which obtain at the present day, and the transition finds little expression in the literature.

About the year 1816 Sir Humphry Davy advanced what has been known ever since as the 'solid particle' theory of luminosity; a theory which went unchallenged for forty-five years and was accepted by practically every one.

He was experimenting upon the combustion taking place in his famous safety lamp and said, "I was led to imagine that the cause of the superiority of the light of a stream of coal gas might be owing to the decomposition of a part of the gas towards the interior of the flame, where the air is in smallest quantity, and the deposition of solid charcoal, which, first by its ignition and afterwards by its combustion, increased to a high degree the intensity of the light; and a few experiments soon convinced me that this was the true solution of the problem." "Whenever a flame is remarkably brilliant and dense, it may always be concluded that some solid matter is produced in it; on the contrary, whenever a flame is extremely feeble and transparent it may be inferred that no solid matter is formed." The idea that solid carbon in the flame is the source of its light was not original with Davy—he says it was suggested by a Mr. Hare—but it was Davy's investigations which put it on a firm basis and he formulated the theory.

Davy showed the relation between the heat and light of flames, the effects of rarefaction and compression of the surrounding air and the influence of cooling and heating. He pointed out also that a luminous flame will deposit carbon on a cold surface, and if rendered non-luminous no carbon can be obtained. These conclusions were immediately accepted and were not seriously disputed until the appearance in 1861 of a communication to the Royal Society from E. Frankland.

In this article Frankland advanced what has come to be known as the 'dense vapor' theory. He and his adherents claimed that, although solid particles in a flame do cause it to emit light, the light from our ordinary illuminating flames is dependent to a great extent upon the presence of dense, transparent, hydrocarbon vapors from which it is radiated, and is not due to the presence of incandescent solid carbon particles. They further claimed that the soot deposited is not carbon, but a mixture of dense hydrocarbons of remarkably high boiling points.

Frankland was led to take up his investigations by seeing a report that candles burned at the same rate on the top of Mt. Blanc as in the valley at its foot; and a second report regarding the retardation of the bursting of shells with time fuses at high elevations in India.

Besides carrying on investigations in artficially rarefied air in his laboratory, he climbed to the top of Mt. Blanc with a goodly supply of standard candles and timed their slow wasting away; probably keeping

warm in the meantime by the fire of his enthusiasm. Many interesting facts were brought to light by these investigations, but his use of them in interpreting the causes of luminosity in ordinary flames led him into error, and, although he found adherents at the time, his views have long since been replaced by those based upon more careful observation. The importance of the work of Frankland lay not so much in what he did as in what he led others to do; and since the publication of his views a great deal has been done by Heumann, Stein, Smithells, Burch, Lewes and others.

Stein disproved Frankland's assertion that soot is a mixture of dense hydrocarbons by showing that it can not be volatilized even by great heat, and that it contains only about nine tenths of one per cent. of hydrogen, which can be separated from it only at high temperatures in an atmosphere of chlorine.

Nor did Frankland's view that glowing, dense vapors cause the light appeal to Heumann, who thought it unlikely that such dense vapors exist in a flame or that there is a sufficiently high temperature to cause them to glow. He knew, of course, that at a temperature like that of an electric arc many gases do glow and give continuous spectra, and that a highly heated gas under pressure acts likewise; but he argued that if carbon really does exist as such in a flame, it most probably is the source of luminosity. To prove its presence or absence he studied the effects upon a flame of heating and cooling it, of diluting and varying the temperature of the gases supplied to it, its transparency and the shadows cast by it, as well as other phenomena; and the results of his experiments led him to give unqualified support to the theory of Davy.

Some account of the salient features at least of Heumann's elaborate investigation must be given in order to convey any idea of his part in firmly fixing the 'solid particle' theory. By allowing a luminous flame to play upon a surface which rapidly conducted heat away from it, like a platinum dish, its luminosity was destroyed. Heating the upper surface of the dish restored the luminosity, and hence Heumann concluded that cooling a flame diminishes its light-giving properties, while heating increases them. He varied the temperature of illuminating gas before it reached the burner and found that the same effects were produced. The heating in some cases increased the normal light-giving power as much as a hundred and twenty-five per cent. Further investigation showed that luminosity can also be diminished or destroyed by rapid oxidation of the hydrocarbons, as well as by diluting them with a neutral gas like nitrogen or carbon dioxide; the effect of dilution being to necessitate a higher temperature for luminosity. He next rendered a flame non-luminous by cooling, introduced chlorine into it to break down the hydrocarbons, and obtained a brilliant light.

A porcelain rod introduced into the lower part of a flame cooled it and decreased its light, but collected no carbon, while, if introduced into the upper part, its *under side* became coated with soot. Heumann argued that if Frankland was right and the light is reflected from dense hydrocarbon vapors, these should be condensed on all sides of the rod at once in a quiet flame, while, as a matter of fact, soot was deposited only on the under side; and furthermore, soot can also be collected upon a surface too hot to condense hydrocarbons at all. He therefore concluded that the surface merely stops carbon which is formed lower down in the flame. If one luminous flame is allowed to play against another, the carbon is rolled up and can be seen as glowing particles in the outer non-luminous sheath.

Frankland had said that flames can not contain solid particles because they are transparent. Heumann pointed out that thick flames are opaque and that thin ones are no more transparent than is an equal layer of soot rising from burning turpentine; the rapidity of the motion of the particles preventing any obstruction to the view, just as is the case with a rapidly revolving, spoked wheel.

Heumann next took up the phenomena of shadows and showed that the luminous portion casts a definite shadow when interposed between sunlight and a screen, and that the shadow is continuous for a luminous turpentine flame and the column of soot above it. And further, that a hydrogen flame which ordinarily casts no shadow and gives no light will cast a sharp shadow and emit a fairly bright light if passed through suspended lampblack or if it sweeps any solid matter into the flame. Luminous vapors do not cast shadows, absorption bands being very different from true shadows.

C. J. Burch found that when sunlight is reflected from a luminous flame it is polarized, while if reflected by glowing vapors, however dense, it does not exhibit this phenomenon. Sunlight which was reflected and refracted by luminous flames was found to exhibit phenomena identical with that reflected and refracted by non-luminous flames rendered luminous by the introduction of solid matter, and also with light reflected and refracted by very finely divided solid matter held in suspension in a liquid. The phenomena presented by like experiments with glowing vapors were totally different. All of Burch's work was confirmed by Stokes some years later.

There was now left no shadow of doubt about carbon being the source of the light rays, and the next question that concerned investigators was the chemical changes which give rise to carbon particles.

Sir Humphry Davy thought the separation of carbon to be due to a decomposition of the hydrocarbon compounds (of which all illuminants are composed) within the flame where the air is in smallest quantity, and no other cause was assigned by other investigators. Prior to

1861 the view, it seems, was that carbon is liberated because of a supposed greater affinity of oxygen for the hydrogen of the hydrocarbon than for the carbon, there not being enough for both. But these points had to be tested.

In the study of the chemical changes that take place, a flame burning at a circular orifice offered the best conditions. As explained in text-books of chemistry, such a flame may be thought of as being made up of an inner, faintly luminous cone fitting into an outer, brightly luminous one—as a finger fits into a glove finger—this latter being surrounded by a non-luminous sheath of water vapor and carbon dioxide. It was desirable to separate these two cones, in order to study the gas after it had left the inner cone and before any change had been brought about by the conditions existing in the outer cone. This separation was first accomplished by Techlu, in France, and Arthur Smithells, in England, working independently, with a piece of apparatus, the essential features of which are pictured in cross-section in Fig. 1. By a proper control of the relative proportions of gas and air the inner cone was made to burn at the orifice *i*, while the outer cone burned at the orifice *o*. The outer cone got its oxygen from the surrounding air, while that for the lower flame was supplied along with the gas. The temperature of each cone was measured and the gases entering and leaving each were analyzed. It was found that as the proportion of gas to air was increased, the tip of the inner or lower cone became *brightly* luminous and a column of soot passed upward through the tube, becoming *faintly* luminous in the outer edge of the upper flame. As soon as the inner cone becomes luminous the unsaturated* hydrocarbon compound known as acetylene begins to appear among the gases passing to the outer cone.

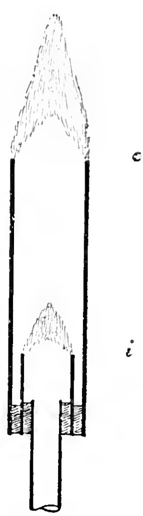


Fig. I.

Vivian B. Lewes now attacked the problem as to how carbon comes to be in the flame in the free state. He analyzed gas drawn from different parts of a coal-gas flame, measured the temperature of its different parts, etc., publishing his results between 1892 and 1895. These results may be stated as follows: Coal-gas consists mainly of a mixture of hydrogen and hydrocarbons, both saturated and unsaturated. In an ordinary 'fishtail' burner flame all hydrogen is consumed before the middle of the luminous portion is reached. Of the *saturated* hydrocarbons about seventy-five per cent. disappears as such in the dark por-

* The terms 'saturated' and 'unsaturated' have reference, among other things, to the relative quantity of hydrogen to carbon in the molecule, an unsaturated compound having relatively less hydrogen than a saturated one.

tion and about twenty-four per cent, is lost in the lower half of the luminous part. In the dark part there occurs a transformation of saturated into unsaturated hydrocarbons, along with a general breaking down of all to yield products less rich in hydrogen and the oxides of carbon. At the point where luminosity just begins, seventy to eighty per cent. of the unsaturated compounds is acetylene, although less than one per cent. was originally present. No acetylene could be found in the flame when it was made non-luminous.

By causing pure gases to pass through tubes heated to known temperatures and analyzing the products formed, Lewes studied the effects of heat upon both saturated and unsaturated hydrocarbons. At 800° C. an unsaturated compound, like ethylene, C_2H_4, breaks down into hydrogen and the still more unsaturated acetylene, C_2H_2. At 1200° C. the very stable, saturated hydrocarbons decompose into acetylene and hydrogen, and the acetylene in turn decomposes into carbon and hydrogen. Even very dense hydrocarbons decompose at 1200° C. These results strengthened Lewes's conviction that under the baking action of the flame-walls in the lower portions acetylene is produced in relatively large quantities and that this is the source of the carbon.

The question which immediately presented itself was, Does there exist in an ordinary flame such conditions of temperature as may bring about the formation of acetylene from the very stable constituents of the illuminants? On measuring the temperatures at various places the necessary temperatures were found to exist.

The work was complete and conclusive and forced a general acceptance of the theory that acetylene is the immediate source of the carbon.

But a yet harder problem presented itself, What gives rise to heat sufficient to make the carbon become incandescent?; a burning question certainly and one not easy to answer.

From the time of Davy to the year 1892 the only opinion was that the burning hydrogen, carbon monoxide and hydrocarbons furnished the heat necessary to raise carbon to incandescence. In that year Lewes advanced his 'latent heat' theory. This theory declared that the latent heat set free when acetylene is decomposed instantly heats the carbon particles thus set free to incandescence.

After showing that the heat of combustion of a flame is only sufficient to render carbon faintly luminous, Lewes compared the temperatures of flames burning coal-gas, the unsaturated hydrocarbon gas, ethylene, and the still less saturated acetylene, and also the amount of light given by each when burning equal volumes of gas per hour from burners best suited to each. He likewise studied the temperatures developed when acetylene is exploded and the localization of the heat set free by its decomposition. His experiments were ingenious and con-

vincing. By comparing ethylene, C_2H_4, with acetylene, C_2H_2 (where for equal consumption the same number of carbon atoms were present), and also with coal-gas, it was seen that the luminous portion of the acetylene flame is not as hot as that of either ethylene or coal-gas, while the illuminating powers of the flames were: acetylene, 240.0 candle power, ethylene, 65.5 c.p. and coal-gas, 16.8 c.p. Evidently the heat of combustion does not account for the incandescence of the carbon; for if it did the cooler acetylene flame would give less light, while, as a matter of fact, it gives twice as much as the ethylene and about fourteen times as much light as the very much hotter coal-gas flame. It was evident that our temperature measuring instruments do not detect the heat of the carbon particles themselves.

To see if luminosity be even partly due to the latent heat of acetylene, Lewes exploded that gas in a closed tube. This was done by wrapping a bit of fulminate of mercury in tissue paper and suspending it by copper wires joined by platinum in contact with the fulminate, and passing an electric current. There followed a brilliant flash of light and a complete decomposition of the gas, and of the eudiometer as

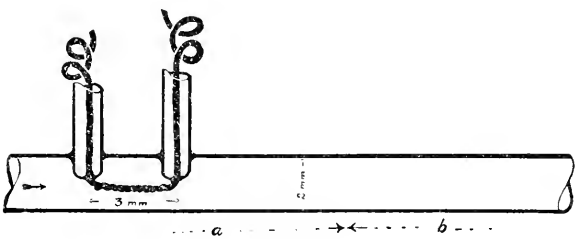


Fig. II

well. Pieces of glass were coated with carbon, and the tissue paper was not scorched except in a small hole where the explosion of the fulminate had burst through. This experiment showed the formation of carbon, the emission of a brilliant light and the localization of the heat liberated. But as the decomposition in a flame can hardly be as rapid as in this experiment, and as hydrogen and oxygen also give a feeble light when exploded, he sought to detect the rise in temperature at the moment of decomposition when this is caused by heat. He arranged a thermo-couple in a small tube so that only the turn of wires was exposed, and after sweeping out the air passed a slow current of acetylene through the tube, the arrangement being as shown in Fig. 2. The heat was raised throughout the tube at a rate of about 10° C. per minute, and almost as soon as the temperature of area *a* passed 800° C. it took a sudden leap to 1000° C., the gas burst into a lurid flame and streams of carbon passed on through the tube. Although the temperature of area *b* was made considerably higher than *a* the carbon

passing through it was not luminous. This experiment would seem to leave no doubt that the incandescence is caused by latent heat, yet further evidence was produced. In another experiment in which diluted acetylene was used it required a higher heat to cause the decomposition and luminosity. This latter is the condition existing in a flame, and the temperature there found is above that required. In other experiments it was found that if the flame temperature were high enough the luminosity was directly proportional to the amount of acetylene in the flame *at the point where luminosity generally begins.* Acetylene was introduced at the corresponding place in a non-luminous flame through very fine holes in a small capillary platinum tube, and the rate of its flow, as well as that of the illuminating gas, was measured and controlled so as to have present the amount of acetylene, which analysis showed to exist in a similar luminous flame. At the holes there was an intense light, and dull red streams of carbon passed upward in the flame.

Lewes sums up his conclusions, drawn from all his work, about as follows: When the hydrocarbon gas leaves the jet at which it is burned, those portions which come in contact with the air are consumed and form a wall of flame, which surrounds the issuing gases. The unburnt gas in its passage through the lower heated area undergoes a number of chemical changes, brought about by the heat radiated from the flame walls; the principal change being the conversion of hydrocarbons into acetylene, hydrogen and methane. The temperature of the flame rapidly increases with the distance from the jet and reaches a point at which it is high enough to decompose acetylene into carbon and hydrogen with a rapidity almost that of an explosion. The latent heat so suddenly set free is localized by the proximity of carbon particles, which by absorbing it become incandescent and emit the larger part of the light given out by the flame; although the heat of combustion causes them to glow somewhat until they come into contact with oxygen and are consumed. This external heating gives rise to little of the light.

There have been opponents to this theory of the cause of luminosity —as there are, fortunately, of all theories—but the evidence is so strong and covers so many points, and so many investigators have confirmed one part or another of the work, that it has been generally accepted as a true statement of the facts with which it deals.

EVOLUTION, CYTOLOGY AND MENDEL'S LAWS.

By O. F. COOK,

U. S. DEPARTMENT OF AGRICULTURE.

THE debt of science to theory is a truism. Bad theories are only less valuable than good ones, and for some purposes they are even better. We do not arrive where we expected to go, but reach an undiscovered country which a more direct route would have left unexplored. The recent history of biology furnishes two excellent examples of the fertility of false theories in the development of the related sciences, embryology and cytology. The theory of organic recapitulation, to the effect that the phylogeny or evolutionary history of natural groups must be repeated in the ontogeny or development of each individual organism promised the student of embryology an easy wealth of scientific discovery, and within a few years hundreds of razors were paring thin the mysteries of evolution. Libraries of new facts were discovered and published, but as our knowledge of life histories increased there was a corresponding decline in the probability that any particular stage in the growth of the individual is necessarily more ancestral than any other. That no general doctrine of recapitulation could be maintained was perceived by Sir John Lubbock as early as 1873,* but vertebrate embryologists did not permit their zeal to be dampened by even the most obvious facts of entomology. Indeed, one of our prominent investigators, finding that recapitulation is elusive by microscopical methods, now proposes to test it by breeding experiments, the results of which may be available in a future geologic epoch.†

The organism having been followed back to its unicellular stage without discovering any process or mechanism by which its adult form was predetermined, believers in such a device must needs seek it inside the cell, and thus was opened another highly fertile field of investigation. Instead of mere homogeneous jelly, surprisingly complicated intracellular structures and processes have been discovered and described, and to identify some of these as the long-sought 'hereditary mechanism' is now the dream of the cytologist.

To judge from his recent article on 'Mendel's Principles of Heredity and the Maturation of the Germ-Cells'‡ Professor Wilson,

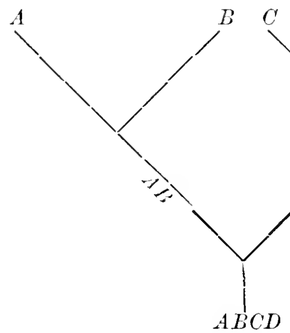
* 'Origin and Metamorphoses of Insects.'

† *Science*, N. S., 16: 506, September 26, 1902.

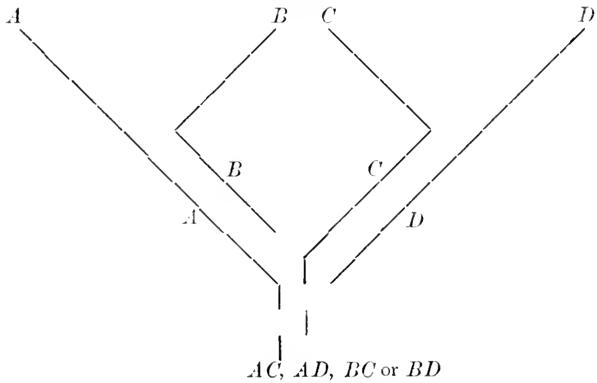
‡ *Science*, N. S., 16: 991, December 19, 1902.

at least, is still very strongly of the belief that the investigator of reproductive cells holds the keys of evolution, and he even finds it remarkable that a general cytological explanation of these 'principles of inheritance' was not suggested before. According to Professor Wilson the facts discovered by Mendel, that in some hybrids, characters of the parents are not permanently combined, are explainable by the 'normal phenomena of maturation,' that is, if we admit that 'individual chromosomes stand in definite relation to transmissible characters,' and that the 'reducing division' by which the reproductive cells are formed 'leads to the separation of paternal and maternal elements and their ultimate isolation as separate germ-cells.' This would be important if true, but the Mendelian facts are unable to accept this proffered support of cytological theory, because they have already demonstrated its falsity.

The commonly accepted view of organic descent may be illustrated by a simple diagram which indicates that a single individual may



inherit characters from all four of its grandparents. Professor Wilson's explanation of Mendel's law would deny this possibility, and would limit the descent of all individuals to two grandparents, so that the form of our family tree would be completely altered.



It would be impossible to have any such compound as *ABCD*, but we should get instead one of the four character-combinations *AC*, *AD*, *BC*, *BD*. The inheritance of a single character from one grandparent would certify the inheritance of all, and thus establish an alibi for the other ancestor of the same side of the house. What a resource for genealogists to be able to prove that a man was no relative of his grandfather, or even that he had no consanguinity with his own brother! Alas that Mendel and other 'experimental evolutionists' have proved that inheritance is by characters and not by chromosomes, if these behave as Professor Wilson indicates. Only the so-called monohybrids, those differing by a single character, would tolerate such an interpretation, and the fallacy of it is obvious as soon as we remember that hybrids may be assembled with reference to two, three or more characters derived from different ancestors. Moreover, Professor Spillman has recently drawn from his experiments with wheat concrete and detailed examples of the fact that definite proportions of such combinations are permanent, since two dominant characters do not antagonize each other.* Unless it be in the case where the varieties crossed differ in but a single character we know of a certainty that the germ-cells are not of pure descent with respect to *parentage*.† The most that can be claimed is that they are organized reciprocally with reference to the *divergent parental characters*, since it seems that the different features may be distributed and recombined quite without reference to the manner in which they were grouped in the parents. In his hybrid wheats Professor Spillman finds all the combinations possible under the mathematical theory of chance. How this could be managed by the chromosomes our cytological friends may be able to conjecture, though from the outside it looks like a rather difficult question.

Hybridization is possible only between groups of common origin, and the characters which show the Mendelian effect are those on which the greatest divergence has taken place. That such characters may be changed about or substituted, and are able to enter freely into all varieties of combination, not only does not prove that the chromosomes are mechanisms of heredity, but it greatly decreases the probability of mechanical theories of evolution, since it shows the facility with which characters may be accumulated in normal interbreeding, before the Mendelian degree of divergence has been reached.

If two plants different in other respects are found to differ also in

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* 'Mendel's Law,' POPULAR SCIENCE MONTHLY, 62:269.

† The theory of Bateson that the germ-cells are pure *with respect to characters* seems to have been misunderstood both by Professor Wilson and by Mr. Cannon in his 'Cytological Basis for the Mendelian Laws' (*Bulletin Torrey Botanical Club*, 29:657, 1902).

chromosomes this does not prove that the chromosomes cause the other differences, even though the differences of the chromosomes interfere with the conjugation of the reproductive cells and thus prevent the hybridization of the plants. Species or varieties seldom, if ever, differ by single characters or at one stage merely, and there is no known reason why related species should not diverge in their single-celled condition as well as at any later period. It is rapidly becoming apparent that the internal organs and functions of cells are as diverse as those of embryos and adult organisms, and as much in need of a general evolutionary explanation.*

The notion that heredity, variation or other phases of evolution are the functions of special organs or mechanisms of cells, has no ascertained basis of fact, and is but an inference from the traditional evolutionary errors that species are normally constant or stable, and that developmental changes are the results of external influences. To move a stationary organism some sort of 'hereditary mechanism' would be needed to bring about the inheritance of characters 'acquired' from the environment, but if we consider that the individuals of a species are normally diverse, and that the species as a whole is normally in motion, a 'hereditary mechanism' becomes quite superfluous, or may be identified with the organism itself, whether in a unicellular or a polycellular stage.

Heredity is the term under which we allude to the fact that organisms exist in series of similar individuals; we have as yet no warrant for holding that it is special 'force' or agency. Crystals of the same substance are thought of as repeatedly taking the same form because of certain properties of matter, not because of a special crystallizing mechanism. The analogy of crystals is, of course, quite inadequate for biological purposes, but we need not reject it entirely, since for all purposes of expression heredity is a general property of living things, and with these there is even less reason than with crystals to seek a cause in the function of a special organ.

Inorganic elements and compounds are homogeneous and similar in all masses or parts; but diversity is the rùle among organisms, no two of which are exact duplicates. The idea of a heredity which maintains identity of structure or form represents no fact in nature. The necessity of continued readjustment is general in life, and is not confined, even in complex organisms, to preliminary stages or to reproductive cells. The individual is not constant nor permanent, but has its own cycle of growth, reproduction and decline, accompanied by continuous changes in all parts of the bodily form and structure.

* Chromosome differences utterly disproportional to the differences of the adult organisms have recently been described by Monkhouse in hybrid fish eggs.

Organisms are not made up merely by the few characters enumerated by the systematist; an infinite number of differing relations of parts might be formulated. Evolutionary divergence is not confined to external adult characters, but may appear in any structure, function or instinct, and at any time in the life history. Species very different as adults may have closely similar young, or larvæ may be much more diverse than the mature insects. Only the inadequacy of our notions of the vital structure and activities has led us to expect that reproductive cells will be found to contain special 'hereditary mechanisms' for the predetermination of the characteristics of adults. The largest and most complex individuals are still groups of cells, and no adequate reason has been shown for believing that particular cells or links of the organic sequence are more hereditary or more determinant than the others. Characters are to be thought of as lines of biological motion, not as structures or entities of reproductive cells. The predetermination of the infinity of structural and morphological characters and positional relations of the millions of cells of the adult by a working model resulting from the conjugation of sexual elements may be dismissed as a crudely anthropomorphic notion of biological processes, as unsupported by facts as it is illogical in conception. Cells have their functions and organs, but evolution is not confined to these; it is also a supercellular or organic process. Cytology is a very interesting branch of descriptive biology, but it enjoys no special evolutionary facilities.

Polycellular organisms grow by the division of cells; but instead of proving that all cells divide in the same way cytologists have found that the same result may be accomplished by a great variety of protoplasmic organs and processes. Unicellular organisms are known to be extremely diverse cytologically, and the cells of compound organisms are, if possible, more so. We know also that the diversity of organisms is not due so much to differences of the individual cells as to differences of number and arrangement in the cell-colonies of which they are constituted.

Heredity is the unknown means by which successive generations of organisms are able to construct themselves in similar, though not identical, forms; it is, in short, an organic memory, and is responsible, not alone for the repetition of the structural type, but also for vast numbers of involuntary functional coordinations and instinctive acts, whether of unicellular or of compound organisms, or of whole colonies of organisms. A colony of social termites is as truly an evolutionary unit as a tree with its many branches, and the cooperative instincts which pervade the individual insects are as truly a hereditary phenomenon as the peculiar arrangement of branches which we term a 'character' of the tree.

To compare heredity with memory explains nothing, of course, since we know as little of the physical basis of the one as of the other, but if the analogy be admitted it will prevent the too confident insistence upon the theory that heredity depends entirely upon positional or other mechanical relations of molecules, or is in some way embodied in particular granules or chromosomes.

But even the most fantastic theories often have some basis of suggestion in fact, and although we can not accept Professor Wilson's cytological explanation of Mendel's laws, nor even share his hope that cytology will elucidate evolution, it is by no means impossible that the normal individual diversity of organisms has a cytological as well as an evolutionary significance. That normal development or growth by cell division is advantaged by cross-fertilization may mean that the cells divide more readily and normally when they contain protoplasmic 'elements' of a proper degree of diversity than when they have only one kind of protoplasm, as would happen in narrow inbreeding, and also when cross-breeding is too wide for the intimate cooperation required for true fertilization. The Mendelian effect would then be explainable on the suggestion of a partial cooperation which has to be abandoned in the formation of new individuals, because, while the organism can follow either of two diverging parental roads with respect to any character, it is, as it were, a stranger to the path that an average would require.

The conjugation of cells may be viewed as a process quite distinct from reproduction, though it is a necessary preliminary to the long series of cell divisions required to build up the complex bodies of the higher animals and plants. As we descend in the organic scale the conjugating cells become more and more similar to each other and to the so-called vegetative or somatic cells of which the body of the organism is composed. Among simple organisms all the cells are alike, including those formed immediately before and after conjugation, and it is not strange that with the diversification of the cells which constitute the various tissues of the plant or animal body the germ cells should become specialized and unlike any of the others. The existence of special reproductive cells among the higher animals and plants is therefore to be looked upon as corresponding to the general complexity of the organism, rather than as an indication of a special mechanism of heredity resident in the germ cells. As founders of new cell-colonies or compound individuals they develop, it appears, on one or the other of divergent parental lines instead of striking out on an untraveled road between.

Notwithstanding their great significance Mendel's laws are negative rather than positive in their bearing upon descent, since we do

not learn from them the nature of that process, but one of its limits. Moreover, the probability that these laws are of general application is greatly lessened by the fact that they are demonstrable only in connection with narrowly inbred and much divergent varieties of plants and animals, to which condition of the experiment the phenomena discovered may prove to be due, rather than to any general fact or mechanism of heredity. It seems certain, however, that neither theory nor experiment will make permanent progress in this direction as long as we continue to confuse under the word hybrid several extremely diverse evolutionary conditions, and fail to realize that generalizations based on any one kind or type of hybrids are quite premature and irrational.

Sterile Hybrids.—The original notion of a hybrid, or at least the most popular meaning of the term, is that of a cross between organic types so widely diverse that the progeny are in some way abnormal or defective, especially with reference to reproduction. Among animals sterile hybrids can not be propagated, but in plants they can be grown from cuttings or buds, and are thus preserved as horticultural 'varieties.'

Aberrant Hybrids.—The second and succeeding generations of hybrids not completely sterile often show striking deviations from both parental types. As these new characters are analogous to the abrupt variations of close-bred plants described by Darwin as 'sports' and more recently renamed 'mutations' by De Vries, it has been suggested that they may be due to the same causes, that is, they may not be in reality the result of crossing, but rather of an inadequate conjugation or defective fertilization which allows a lapse from the normal form. Both mutations and mutative hybrids are comparatively infertile, so that their suddenly attained new characters should not be looked upon as true contributions to evolutionary progress.

Reciprocal or Mendelian Hybrids.—Mendel and his successors have proved that there is still a third type of less abnormal hybrids, in which there is no permanent combination or averaging of divergent parental characters, although it is not known that vigor and fertility are notably diminished. Mendel's so-called laws are generalized statements of the results of his experiments upon the crossing of different garden varieties of the pea; he himself found that the same was not true among hybrids of *Hieracium*.* A part of the scientific com-

* The question has been raised as to whether Mendel's discoveries should be called 'laws.' The present view would deny to them universal application as 'laws' or 'principles' of heredity, though it admits as probable their general truth for a certain evolutionary condition or stage.

Laws of gases are not called laws of matter, and do not apply until matter reaches the gaseous state. Similarly, there can be no objection to

munity which a few years ago was properly characterized as more Darwinian than Darwin might now be described as more Mendelian than Mendel, and expects to find in 'Mendel's laws' an explanation of heredity, to say nothing of other things. Crosses between some twenty-six close-bred varieties of plants and animals have been found to 'Mendelize,' as the new expression is, and it may be expected that others will do the same wherever the conditions of the experiment can be met, though no amount of similar facts would justify the general conclusions which some recent writers have so promptly drawn. 'Mendel's laws' have already had many different statements, but the most that can be said with certainty is that after close-bred varieties of a plant or animal have sufficiently separated, their divergent characters do not again blend or reduce to an average, but draw apart into definite proportions of each succeeding generation of offspring. Obviously, this is not a method or law of inheritance, but of non-inheritance or fractional inheritance. The sterile and aberrant hybrids are evidence that too wide crossing is not advantageous and makes no contribution to evolutionary progress. Mendel's experiments afford further evidence of the same fact, in that the organisms themselves are found to have means of dissolving such alliances and thus of holding to the paths on which their varietal divergencies have gone forward. The theory that hybridization assists evolution by encouraging variability is shown to have a distinct limit, since little evolutionary progress would come from mere combination of the stable or divergent characters which are a prerequisite of the Mendelian experiments.

Synthetic or Blended Hybrids.—If the normal flexibility of the organism has not been diminished by narrow segregation or inbreeding, the Mendelian repugnance of divergent characters does not appear; Mendel's law of reciprocal characters gives place to Spillman's law of blended or graded characters.* Thus there is no record of a normal straight-haired white child as the offspring of two mulattoes. Inbreeding to an extent far beyond anything usual in nature is the rule among domesticated plants and animals, but if the varieties are not too divergent they cross freely and with obvious advantage, as shown by increase in vigor, though such 'new characters' soon disappear under renewed inbreeding. Characters which would become dominant in the Mendelian hybrids are in the less divergent stages termed prepotent, that is, they are impressed with increased intensity upon increasing numbers of each successive generation. On the other

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such expressions as 'Mendel's laws of the disjunction of characters in hybrids,' or 'Mendel's laws of reciprocal hybrids.'

* '* * * hybrids show every possible gradation between the characters of the two parents.'

hand, characters acquired through inbreeding or other debilitating causes may disappear or become recessive as soon as crossing permits a return to a more normal and vigorous ancestral type of organization, as in the historic pigeon experiments of Darwin. The popularization of Mendel's laws should make it more easy to perceive that the normal effect of cross-breeding is a progressive synthetic evolution and not a stationary average, though we are having some fine examples of the lengths to which the specialist will sometimes go to escape facts too simple and obvious for his appreciation.

Individual 'Hybrids.'—Perhaps the loosest use of the word hybrid is for the offspring of crosses between so-called 'horticultural varieties' of domesticated plants propagated by cuttings or grafts. Everybody knows, though some forget, that the Baldwin apple, the Bartlett pear, the Niagara grape, and a great multitude of analogous sorts, are descending from single seedling trees or vines, and are thus for evolutionary purposes single individuals. The distinction between such individuals and those of wild species in nature is largely psychological; we have learned to regard differences between individual apple trees, but have not attained such close acquaintance with oaks and elms. If crosses between the normally diverse individuals of a species are to be termed hybrids then the word covers all sexually differentiated organisms and is utterly useless as a means of drawing biological distinctions. Mendel deliberately disregarded the question as to which of his pea hybrids were between different species, and which between varieties merely, and for the purposes of his inquiry this was a matter of little importance. But for his followers to draw general conclusions, while ignoring all distinction between the evolutionary conditions of the organisms which they study, is a reversion to the same general woolliness of evolutionary thinking to which Mendel constituted so brilliant an exception.

The millions of species with which nature has been experimenting for millions of years seem to make it very plain that individual diversity with free interbreeding is the optimum condition for evolutionary progress, since this is what we find everywhere among natural species. It is true that the diversity masks the slow and gradual motion of the species from perception by our momentary observations, and also that the interbreeding hinders the segregation of species; but we may take the results as evidence that evolutionary progress is not impeded by wide individual variation, nor by opportunities for the progressive accumulation of new characters. Nor need we turn our backs on this interpretation of the history of organic nature because Mendel and others have given new demonstrations of the old fact that there are degrees of evolutionary divergence in which the combination of parental characters is no longer possible.

Mendel's laws are of much practical importance because they make plain to breeders of economic plants and animals that they can not do what has been attempted so frequently, make improved breeds by combining the divergent characters of close-bred varieties. The Mendelian facts are of general evolutionary interest, not because they explain descent, but because they are incompatible with the commonly accepted static theories of development which hold that evolutionary progress is due to external or environmental influences and overlook the independent self-caused motion of species. More detailed presentation of the latter view can not be undertaken here;* it must suffice for the present to have pointed out that cytology has not proved the universality of Mendel's laws as 'principles of inheritance,' nor do the laws prove that the chromosomes are the long-sought 'hereditary mechanisms.'

Heredity should be thought of as a general property of organisms, and not as the function of a special organ of the cell or of the embryo. As a phenomenon it should be associated with crystallization, on the one side, and with memory, on the other. There may be simpler properties of matter which render crystallization, heredity and memory possible, but such properties are not yet recognized in physics and chemistry, so that the terms and theories of these sciences are of little use in the discussion of evolution.

Viewed as the basis of an independent generalization the Mendelian experiments ran counter to multitudes of the most obvious and best established data of biology, and it may have been on this account that they were so long disregarded. The apparent conflict is here explained as due to erroneous theories of evolution; the recognition of spontaneous organic motion enables Mendel's facts to find a place in the evolutionary series, and renders the general inferences of de Vries, Bateson and Wilson unnecessary. Nor need the present view be thought to depreciate the importance of Mendel's laws, since such discoveries are of much greater practical value after they have found their true place among related facts than while as novelties they are permitted to obscure all the adjoining fields of investigation.

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* See 'A Kinetic Theory of Evolution,' *Science*, N. S., 13: 969, June 21, 1901.

THE PEARL FISHERIES OF CEYLON.*

By Professor W. A. HERDMAN, B.Sc., F.R.S.,
UNIVERSITY COLLEGE, LIVERPOOL.

THE celebrated pearl 'oysters' of Ceylon are found mainly in certain parts of the wide shallow plateau which occupies the upper end of the Gulf of Manaar, off the northwest coast of the island and south of Adam's Bridge.

The animal (*Margaritifera vulgaris*, Schum. = *Avicula fucata*, Gould) is not a true oyster, but belongs to the family Aviculidæ, and is, therefore, more nearly related to the mussels (*Mytilus*) than to the oysters (*Ostræa*) of our seas.

The fisheries are of very great antiquity. They are referred to by various classical authors, and Pliny speaks of the pearls from Taprobane (Ceylon) as 'by far the best in the world.' Cleopatra is said to have obtained pearls from Aripu, a small village on the Gulf of Manaar, which is still the center of the pearl industry. Coming to more recent times, but still some centuries back, we have records of fisheries under the Singhalese kings of Kandy, and subsequently under the successive European rulers—the Portuguese being in possession from about 1505 to about 1655, the Dutch from that time to about 1795, and the English from the end of the eighteenth century onwards. A notable feature of these fisheries under all administrations has been their uncertainty.

The Dutch records show that there were no fisheries between 1732 and 1746, and again between 1768 and 1796. During our own time the supply failed in 1820 to 1828, in 1837 to 1854, in 1864 and several succeeding years, and finally after five successful fisheries in 1887, 1888, 1889, 1890 and 1891 there has been no return for the last decade. Many reasons, some fanciful, others with more or less basis of truth, have been given from time to time for these recurring failures of the fishery; and several investigations, such as that of Dr. Kelaart (who unfortunately died before his work was completed) in 1857 to 1859, and that of Mr. Holdsworth in 1865 to 1869, have been undertaken without much practical result so far.

In September, 1901, Mr. Chamberlain asked me to examine the records and report to him on the matter, and in the following spring I was invited by the government to go to Ceylon with a scientific assistant, and undertake any investigation into the condition of the

* Abstract of discourse before the Royal Institution of Great Britain.

banks that might be considered necessary. I arrived at Colombo in January, 1902, and as soon as a steamer could be obtained proceeded to the pearl banks. In April it was necessary to return to my university duties in Liverpool, but I was fortunate in having taken out with me as my assistant, Mr. James Hornell, who was to remain in Ceylon for at least a year longer, in order to carry out the observations and experiments we had arranged, and complete our work. This program has been carried out, and Mr. Hornell has kept me supplied with weekly reports and with specimens requiring detailed examination.

The steamship *Lady Havelock* was placed by the Ceylon government at my disposal for the work of examining into the biological conditions surrounding the pearl oyster banks; and this enabled me on two successive cruises of three or four weeks each to examine all the principal banks, and run lines of dredging and trawling and other observations across, around and between them, in order to ascertain the conditions that determine an oyster bed. Towards the end of my stay I took part in the annual inspection of the pearl banks, by means of divers, along with the retiring Inspector, Captain J. Donnan, C.M.G., and his successor, Captain Legge. During that period we lived and worked on the native barque *Rangasameeporawee,* and had daily opportunity of studying the methods of the native divers and the results they obtained.

It is evident that there are two distinct questions that may be raised—the first as to the abundance of the adult 'oysters,' and the second as to the number of pearls in the oysters, and it was the first of these rather than the frequency of the pearls that seemed to call for investigation, since the complaint has not been as to the number of pearls per adult oyster, but as to the complete disappearance of the shell-fish. I was indebted to Captain Donnan for much kind help during the inspection, when he took pains to let me see as thoroughly and satisfactorily as possible the various banks, the different kinds and ages of oysters, and the conditions under which these and their enemies exist. I wish also to record my entire satisfaction with the work done by Mr. Hornell, both while I was with him and also since. It would have been quite impossible for me to have got through the work I did in the very limited time had it not been for Mr. Hornell's skilled assistance.

Most of the pearl oyster banks or 'paars' (meaning rock or any form of hard bottom, in distinction to 'Manul,' which indicates loose or soft sand) are in depths of from five to ten fathoms and occupy the wide shallow area of nearly fifty miles in length, and extending opposite Aripu to twenty miles in breadth, which lies to the south of Adam's Bridge. On the western edge of this area there is a steep

declivity, the sea deepening within a few miles from under ten to over one hundred fathoms; while out in the center of the southern part of the Gulf of Manaar, to the west of the Chilaw Pearl Banks, depths of between one and two thousand fathoms are reached. On our two cruises in the *Lady Havelock* we made a careful examination of the ground in several places outside the banks to the westward, on the chance of finding beds of adult oysters from which possibly the spat deposited on the inshore banks might be derived. No such beds, outside the known 'paars,' were found; nor are they likely to exist. The bottom deposits in the ocean abysses to the west of Ceylon are 'globigerina ooze,' and 'green mud,' which are entirely different in nature and origin from the coarse terrigenous sand, often cemented into masses, and the various calcareous neritic deposits, such as corals and nullipores, found in the shallow water on the banks. The steepest part of the slope from ten to twenty fathoms down to about 100 fathoms or more, all along the western coast seems in most places to have a hard bottom covered with Alcyonaria, sponges, deep-sea corals and other large encrusting and dendritic organisms. Neither on this slope nor in the deep water beyond the cliff did we find any ground suitable for the pearl oyster to live upon.

Close to the top of the steep slope, about twenty miles from land, and in depths of from eight to ten fathoms, is situated the largest of the 'paars,' the celebrated Periya Paar, which has frequently figured in the inspectors' reports, has often given rise to hopes of great fisheries, and has as often caused deep disappointment to successive government officials. The Periya Paar runs for about eleven nautical miles north and south, and varies from one to two miles in breadth, and this—for a paar—large extent of ground becomes periodically covered with young oysters, which, however, almost invariably disappear before the next inspection. This paar has been called by the natives the 'mother-paar' under the impression that the young oysters that come and go in fabulous numbers migrate or are carried inwards and supply the inshore paars with their populations. During a careful investigation of the Periya Paar and its surroundings we satisfied ourselves that there is no basis of fact for this belief; and it became clear to us that the successive broods of young oysters on the Periya Paar, amounting probably within the last quarter century alone to many millions of millions of oysters, which if they had been saved would have constituted enormous fisheries, have all been overwhelmed by natural causes, due mainly to the configuration of the ground and its exposure to the southwest monsoon.

The following table shows, in brief, the history of the Periya Paar for the last twenty-four years:

Feb. 1880.	Abundance of young oysters.
Mar. 1882.	No oysters on the bank.
Mar. 1883.	Abundance of young oysters, 6 to 9 months old.
Mar. 1884.	Oysters still on bank, mixed with others of 3 months old.
Mar. 1885.	Older oysters gone, and very few of the younger remaining.
Mar. 1886.	No oysters on bank.
Nov. 1887.	Abundance of young oysters, 2 to 3 months.
Nov. 1888.	Oysters of last year gone and new lot come, 3 to 6 months.
Nov. 1889.	Oysters of last year gone; a few patches 3 months old present.
Mar. 1892.	No oysters on the bank.
Mar. 1893.	Abundance of oysters of 6 months old.
Mar. 1894.	No oysters on bank.
Mar. 1895.	Ditto.
Mar. 1896.	Abundance of young oysters, 3 to 6 months.
Mar. 1897.	No oysters present.
Mar. 1898.	Ditto.
Mar. 1899.	Abundance of oysters, 3 to 6 months old.
Mar. 1900.	Abundance of oysters 3 to 6 months old; none of last year's remaining.
Mar. 1901.	Oysters present of 12 to 18 months of age, but not so numerous as in preceding year.
Mar. 1902.	Young oysters abundant, 2 to 3 months. Only a few small patches of older oysters (2 to 2½ years) remaining.
Nov. 1902.	All the oysters gone.

It is shown by the above that since 1880 the bank has been naturally restocked with young oysters at least eleven times without yielding a fishery.

The ten-fathom line skirts the western edge of the paar, and the one hundred-fathom line is not far outside it. An examination of the great slope outside is sufficient to show that the southwest monsoon running up towards the Bay of Bengal for six months in the year, must batter with full force on the exposed seaward edge of the bank and cause great disturbance of the bottom. We made a careful survey of the Periya Paar in March, 1902, and found it covered with young oysters a few months old. In my preliminary report to the government written in July, I estimated these young oysters at not less than a hundred thousand millions, and stated my belief that these were doomed to destruction, and ought to be removed at the earliest opportunity to a safer locality further inshore. Mr. Hornell was authorized by the Governor of Ceylon to carry out this recommendation, and went to the Periya Paar early in November with boats and appliances suitable for the work, but found he had arrived too late. The southwest monsoon had intervened, the bed had apparently been swept clean, and the enormous population of young oysters, which we had seen in March, and which might have been used to stock many of the smaller inshore paars, was now in all probability either buried in sand or carried down the steep declivity into the deep water outside. This experience, taken

along with what we know of the past history of the bank as revealed by the inspectors' reports, shows that whenever young oysters are found on the Periya Paar, they ought, without delay, to be dredged up in the bulk and transplanted to suitable ground in the Cheval district—the region where the most reliable paars are placed.

From this example of the Periya Paar it is clear that in considering the vicissitudes of the pearl oyster banks, we have to deal with great natural causes which can not be removed, but which may to some extent be avoided, and that consequently, it is necessary to introduce large measures of cultivation and regulation in order to increase the adult population on the grounds, give greater constancy to the supply, and remove the disappointing fluctuations in the fishery.

There are in addition, however, various minor causes of failure of the fisheries, some of which we were able to investigate. The pearl oyster has many enemies, such as star-fishes, boring sponges which destroy the shell, boring molluscs which suck out the animal, internal protozoan and vermean parasites and carnivorous fishes, all of which cause some destruction and which may conspire on occasions to ruin a bed and change the prospects of a fishery. But in connection with such zoological enemies, it is necessary to bear in mind that from the fisheries point of view their influence is not wholly evil, as some of them are closely associated with pearl production in the oyster. One enemy (a Plectognathid fish) which doubtless devours many of the oysters, at the same time receives and passes on the parasite which leads to the production of pearls in others. The loss of some individuals is in that case a toll that we very willingly pay, and no one would advocate the extermination of that particular enemy.

In fact the oyster can probably cope well enough with its animate environment if not too recklessly decimated at the fisheries, and if man will only compensate to some extent for the damage he does by giving some attention to the breeding stock and 'spat,' and by transplanting when required the growing young from unsuitable ground to known and reliable 'paars.'

Those were the main considerations that impressed me during our work on the banks, and, therefore, the leading points in the conclusions given in my preliminary report (July, 1902) to the governor of Ceylon ran as follows:

1. The oysters we met with seemed on the whole to be very healthy.

2. There is no evidence of any epidemic or of much disease of any kind.

3. A considerable number of parasites, both external and internal, both protozoan and vermean, were met with, but that is not unusual in molluscs, and we do not regard it as affecting seriously the oyster population.

4. Many of the larger oysters were reproducing actively.

5. We found large quantities of minute 'spat' in several places.

6. We also found enormous quantities of young oysters a few months old on many of the paars. On the Periya Paar the number of these probably amounted to over a hundred thousand million.

7. A very large number of these young oysters never arrive at maturity. There are several causes for this:

8. They have many natural enemies, some of which we have determined.

9. Some are smothered in sand.

10. Some grounds are much more suitable than others for feeding the young oysters, and so conducing to life and growth.

11. Probably the majority are killed by overcrowding.

12. They should therefore be thinned out and transplanted.

13. This can be easily and speedily done, on a large scale, by dredging from a steamer, at the proper time of year, when the young oysters are at the best age for transplanting.

14. Finally there is no reason for any despondency in regard to the future of the pearl oyster fisheries, if they are treated scientifically. The adult oysters are plentiful on some of the paars and seem for the most part healthy and vigorous; while young oysters in their first year, and masses of minute spat just deposited, are very abundant in many places.

To the biologist two dangers are however evident, and, paradoxical as it may seem, these are *overcrowding* and *overfishing*. But the superabundance, and the risk of depletion are at the opposite ends of the life cycle, and, therefore, both are possible at once on the same ground—and either is sufficient to cause locally and temporarily a failure of the pearl oyster fishery. What is required to obviate these two dangers ahead, and ensure more constancy in the fisheries, is careful supervision of the banks by some one who has had sufficient biological training to understand the life-problems of the animal, and who will therefore know when to carry out simple measures of farming, such as thinning and transplanting, and when to advise as to the regulation of the fisheries.

In connection with cultivation and transplantation, there are various points in structure, reproduction, life-history, growth and habits of the oyster which we had to deal with, and some of which we were able to determine on the banks, while others have been the

subject of Mr. Hornell's work since, in the little marine laboratory we established at Galle.

Although Galle is at the opposite end of the island from the pearl banks of Manaar, it is clearly the best locality in Ceylon for a marine laboratory—both for general zoology and also for working at pearl oyster problems. Little can be done on the sandy exposed shores of Manaar island or the Bight of Condatchy—the coasts opposite the pearl banks. The fisheries take place far out at sea, from ten to twenty miles off shore; and it is clear that any natural history work on the pearl banks must be done not from the shore, but, as we did, at sea from a ship during the inspections, and can not be done at all during the monsoons because of the heavy sea and useless exposed shore. At such times the necessary laboratory work supplementing the previous observations at sea can be carried out much more satisfactorily at Galle than anywhere in the Gulf of Manaar.

Turning now from the health of the oyster population on the 'paars,' to the subject of pearl formation, which is evidently an unhealthy and abnormal process, we find that in the Ceylon oyster there are several distinct causes that lead to the production of pearls. Some pearls or pearly excrescences on the interior of the shell are due to the irritation caused by boring sponges and burrowing worms. Minute grains of sand and other foreign bodies gaining access to the body inside the shell, which are popularly supposed to form the nuclei of pearls, only do so, in our experience, under exceptional circumstances. Out of the many pearls I have decalcified, only one contained in its center what was undoubtedly a grain of sand; and from Mr. Hornell's notes taken since I left Ceylon, I quote the following passage, showing that he has had a similar experience:

"February 16, 1903—*Ear-pearls.* Of two decalcified, one from the anterior ear (No. 148), proved to have a minute quartz grain (micro. preparation 25) as nucleus."

It seems probable that it is only when the shell is injured, as, for example, by the breaking off or crushing of the projecting 'ears,' thereby enabling some fine sand to gain access to the interior, that such inorganic particles supply the irritation which gives rise to pearl formation.

The majority of the pearls found free in the tissues of the body of the Ceylon oyster contain, in our experience, the more or less easily recognizable remains of Platyelmian parasites; so that the stimulation which causes eventually the formation of an 'orient' pearl is, as has been suggested by various writers in the past, due to infection by a minute lowly worm, which becomes encased and dies, thus justifying,

in a sense, Dubois' statement that—'La plus belle perle n'est donc, en définitive, que le brillant sarcophage d'un ver.'*

To Dr. Kelaart (1859) belongs the honor of having first connected the formation of pearls in the Ceylon oyster with the presence of vermean parasites. It is true that Filippi seven years before (in 1852), showed that the Trematode *Distomum duplicatum* was the cause of pearl formation in the fresh-water mussel *Anodonta*, and Küchenmeister (1856), Moebius (1857) and others extended the discovery to some of the larger pearl oysters, and to other parasites; but it is probable that Kelaart knew nothing of these papers and that he made his discovery in regard to the Ceylon oyster quite independently. He (and the Swiss zoologist, Humbert, who was with him at a pearl fishery) found "in addition to the filaria and cercaria, three other parasitical worms infesting the viscera and other parts of the pearl oyster. We both agree that these worms play an important part in the formation of pearls; and it may yet be found possible to infect oysters in other beds with these worms, and thus increase the quantity of these gems."

Thurston, in 1894, confirmed Kelaart's observation, finding in the tissues, and also in the alimentary canal, of the Ceylon oyster, 'larvæ of some Platyhelminthian (flat-worm).'

Garner (1871) associated the production of pearls both in the pearl oysters and also in our common English mussel (*Mytilus edulis*) with the presence of Distomid parasites; Giard (1897) and other French writers have made similar observations in the case of *Donax* and other Lamellibranchs; and Dubois (1901) has more recently ascribed the production of pearls in mussels on the French coast, to the presence of the larva of *Distomum margaritarum*. Jameson (1902) then followed with a more detailed account of the relations between the pearls in *Mytilus* and the Distomid larvæ, which he identifies as *Distomum* (*Brachycœlium*) *somateriæ* (Levinson). Jameson's observations were made on mussels obtained partly at Billiers (Morbihan), a locality at which Dubois had also worked, and partly at the Lancashire Sea-Fisheries Marine Laboratory at Piel in the Barrow Channel. Finally, Dubois has just published a further note† in which, referring to the causation of pearls in *Mytilus*, he says (p. 178): "En somme ce que ce dernier [Garner] avait vu en Angleterre en 1871, je l'ai retrouvé en Bretagne en 1901. Quelques jours après mon départ de Billiers, M. Lyster Jameson, de Londres, est venu dans la même localité et a confirmé le fait observé par Garner et par moi." But Jameson has done rather more than that. He has shown that it is prob-

* *Comptes Rendus*, October 14, 1901.

† *Comptes Rendus Acad. d. Sci.*, January 19, 1903.

able (his own words are 'there is hardly any doubt') that the parasite causing the pearl-formation in our common mussel (not in the Ceylon 'pearl oyster') is the larva of *Distomum somateriæ*, from the eider duck and the scoter. He also believes that the larva inhabits *Tapes* or the cockle as a first host before getting into the mussel.

We have found, as Kelaart did, that in the Ceylon pearl oyster there are several different kinds of worms commonly occurring as parasites, and we shall I think be able to show in our final report that Cestodes, Trematodes and Nematodes are all concerned in pearl formation. Unlike the case of the European mussels, however, we find so far that in Ceylon the most important cause is a larval Cestode of the Tetrarhynchus form. Mr. Hornell has traced a considerable part of the life history of this parasite, from an early free-swimming stage to a late larval condition in the file fish (*Balistes mitis*) which frequents the pearl banks and preys upon the oysters. We have not yet succeeded in finding the adult, but it will probably prove to infest the sharks or other large Elasmobranchs which devour *Balistes*.

It is only due to my excellent assistant, Mr. James Hornell, to state that our observations on pearl formation are mainly due to him. During the comparatively limited time (under three months) that I had on the banks I was mainly occupied with what seemed the more important question of the life-conditions of the oyster, in view of the frequent depletion of particular grounds.

It is important to note that these interesting pearl-formation parasites are not only widely distributed over the Manaar banks, but also on other parts of the coast of Ceylon. Mr. Hornell has found *Balistes* with its Cestode parasite both at Trincomalie and at Galle, and the sharks also occur all round the island, so that there can be no question as to the probable infection of oysters grown at these or any other suitable localities.

There is still, however, much to find out in regard to all these points, and other details affecting the life of the oyster and the prosperity of the pearl fisheries. Mr. Hornell and I are still in the middle of our investigations, and this must be regarded as only a preliminary statement of results which may have to be corrected, and I hope will be considerably extended in our final report.

It is interesting to note that the *Ceylon Government Gazette*, of December 22 last, announced a pearl fishery, to commence on February 22, during which the following banks would be fished:

The southeast Cheval Paar, estimated to have 49 million oysters.

The East Cheval Paar, with 11 millions.

The Northeast Cheval Paar, with 13 millions.

The Periya Paar Kerrai, with 8 million—making in all over 80 million oysters.

That fishery is now in progress, Mr. Hornell is attending it, and we hope that it may result not merely in a large revenue from pearls but also in considerable additions to our scientific knowledge of the oysters.

As an incident of our work in Ceylon, it was found necessary to fit up the scientific man's workshop—a small laboratory on the edge of the sea, with experimental tanks, a circulation of sea-water and facilities for microscopic and other work. For several reasons, as was mentioned above, we chose Galle at the southern end of Ceylon, and we have every reason to be satisfied with the choice. With its large bay, its rich fauna and the sheltered collecting ground of the lagoon within the coral reef, it is probably one of the best possible spots for the naturalist's work in eastern tropical seas.

In the interests of science it is to be hoped, then, that the marine laboratory at Galle will soon be established on a permanent basis with a suitable equipment. It ought, moreover, to be of sufficient size to accommodate two or three additional zoologists, such as members of the staff of the museum and of the medical college at Colombo, or scientific visitors from Europe. The work of such men would help in the investigation of the marine fauna and in the elucidation of practical problems, and the laboratory would soon become a credit and an attraction to the colony. Such an institution at Galle would be known throughout the scientific world, and would be visited by many students of science, and it might reasonably be hoped that in time it would perform for the marine biology and the fishing industries of Ceylon very much the same important functions as those fulfilled by the celebrated gardens and laboratory at Peradeniya for the botany and associated economic problems of the land.

A COMPARISON OF LAND AND WATER PLANTS.

By Professor GEORGE JAMES PEIRCE, Ph.D.,
LELAND STANFORD JR. UNIVERSITY.

THE aquatic origin of all living things is now a generally accepted conception. The arguments in its favor are: (1) morphological, based on comparative studies of the vegetative and reproductive parts; (2) biological, based on observation of the habits of plants and animals, especially at the breeding season; (3) paleontological, based on the now known fossil remains of formerly living organisms; (4) physiological, based on the absolute dependence of all living things on water. These last arguments appeal to me more strongly than any others. When we realize that all food, all the materials of which the body is constructed, and all the substances which its cells use, can enter the cells only in solution in water, we see at once how indispensable water is. When we realize besides that the form and size of the cells, and therefore of the body, depend upon the pressures within the cells which are due to the presence of aqueous solutions therein, we see how necessary water is in another way. Upon the tension of the cells depends the mechanical force which they, the tissues, and the organism, can exert. The absolute dependence of all living things upon water is one of the two most important characters which they possess. The amount of water which different cells, organs and organisms use varies greatly, but they all require some water. The ease with which different organisms, organs and cells obtain water also varies, though not necessarily in a degree corresponding with the amounts used. If we compare the conditions under which water and land plants live, we shall see some reasons for the differences in the structure and habits of these two classes.

The constantly submersed aquatic, whether fresh or salt water, is buoyed up with a very considerable force. A solid mass of plant tissue from which all air and water had been pressed would be buoyed up in water by a force from seven to eight hundred times as great as would be exerted if it were in the air. This is in accordance with Archimedes' well-known law in physics—a body in a fluid is buoyed up with a force equal to the weight of the volume of fluid which it displaces. Any part of a land plant, therefore, which rises into the air is supported with say only one seven hundredth of the force which supports the submersed aquatic. This difference is met by the land plant in two ways. It develops tissues which mechanically support it, which carry that part

of its weight which the air can not carry; and it so constructs certain parts, for instance the leaves, of nearly all but the pines and their allies, that their form is best fitted for floating. The leaves are the organs in which most food is made. Their efficiency depends upon the amount of light which they can absorb, and they will evidently absorb most light if they are flat and placed at right angles to the rays as they come from the sun. This may be the main reason for the expanded form of the leaves, and it is the only reason which has been proved by experiment. But it is evident that a leaf is buoyed up more strongly and, therefore, requires less mechanical support if it is flat and more oı less horizontal than if it were vertical or if it were cylindrical or cubical. Comparing weight for weight, we find more mechanical tissue iı the pine-needle than in the flat leaf. And we find no such mechanical tissues even in the largest and longest submersed aquatics, some of which are as long as trees are tall.

The amount of mechanically strengthening tissue in a part or a plant has been proved by experiment to depend upon the amount of mechanical strain to which it is exposed. Garden plants which ordinarily carry the weight of their branches will be mechanically much weaker if supported on trellises. Conversely climbers and prostrate plants, if subjected to mechanical pull, will develop strengthening tissues which they ordinarily do not form. In these cases, the so-called inherited tendency to form or not to form mechanically strengthening tissues is so promptly overcome in the individuals experimented upon as to suggest some doubt whether there is such a tendency at all, whether the structure and behavior of living things is not more due to the influence of their surroundings than to inheritance.

We may conclude, then, that the presence in erect land plants of mechanically supporting tissues which are never found in submersed aquatics is not mere coincidence. The difference in the mechanical tissues of these plants is due, not to the differences in their places in any scheme of classification or to their degree of evolution, but to the differences in the buoyancy of air and water. Aquatic plants do develop mechanical tissues, but they resist the pullings, bendings and blunt blows which the waves give. These tissues can not support much weight.

The strength of the submersed aquatic will vary greatly according as it is a floating or an attached organism. All submersed aquatics which are unattached are mechanically weak and they are usually small, whereas those which are attached must develop a certain amount of mechanical strength to resist the tugging of the free parts against the holdfasts. Compare, for instance, *Spirogyra* and fresh-water *Cladophora,* plants of somewhat similar size, structure and situation. A *Cladophora* filament will break only under a much stronger pull than

a *Spirogyra* filament of the same size and general structure growing in the same pool. *Cladophora* grows attached, *Spirogyra* is free. Compare *Nereocystis* and *Macrocystis*, the great kelps of the Pacific, with the *Sargassum* of the Atlantic. *Sargassum* begins life as an attached plant but is mechanically weak, is broken away and is for most of its life free. Our Pacific kelps are always attached and are tremendously tough. The comparison is not fair, however, for *Sargassum* is smaller than our giant kelps.

The attached plants between the tide-marks are among the most interesting as to mechanical strength. The rock weeds (*Fucus*), the *Irideas*, the *Gigartinas*, etc., of our Pacific shore withstand a tremendous amount of pulling and buffeting and are very hard to pull, though comparatively easy to tear, to pieces. These and other thinner and more delicate plants, *e. g.*, the *Ulvas*, *Porphyras*, etc., escape destruction by their extreme pliancy rather than by toughness.

The most striking example of mechanical strength displayed by any plant living between the tide-marks is furnished by the sea palm (*Postelsia*), which is peculiar to the Pacific coast. This plant grows to a height of twelve to eighteen inches. The erect and smooth tapering trunk rises from the tangled mass of holdfasts attaching it to the flat or shelving ledge. The leaves, often over half as long as the trunk, narrow and corrugated, spring from its top. The trunk is like that of an erect land plant in being able to support a considerable weight applied vertically. The sea palm resembles in carrying power the land plant which gave it its name, but its remarkable strength is shown by its living where almost nothing else can, where the constantly beating surf is too much even for barnacles unless they take hold in some crevice. The spores must germinate very rapidly in the short times of comparative quiet, taking fast hold of the rock, for in most places where I have seen the sea palm growing, the waves were constantly in motion, and usually so violent, even at low water, that a man would be carried off his feet almost instantly. The sea palm bows before a breaker, bends away from it, resists its downward crushing force, holds on and holds together in spite of the shoreward thrust and seaward pull, thrives only where the sea is roughest, is the only plant where it grows every part of which has not fast hold of the rock.

Turning from the relative buoyancy of air and water and the effect of this difference in the supporting tissues of land and water plants, we may examine the relative ease with which land and water plants obtain their food-materials. The means by which any organism takes food or food materials into its living cells are simple though not generally enough understood. Only when the aqueous solution in the cell, permeating all its parts including the wall, is in contact with

an aqueous solution outside the cell, can there be any absorption. The submersed aquatic has many or all of its cells in direct contact with the water. The land plant has only those cells which touch, or are in, the soil which are regularly in direct contact with water. Except those plants living in swamp or marsh, and except immediately after heavy rain, land plants are able to obtain only those thin films of water held on the surfaces of the soil particles. To reach these films, to bring the solution within the cells into contact with the water (also a solution) on the soil particles, land plants develop hairs—the rhizoids of the lower forms, the root-hairs of the higher. An aquatic composed of a chain or of a film of cells has all its cells directly in contact with the water, which holds in solution oxygen, carbon dioxide, and those mineral salts which constitute its food materials. An aquatic composed of a mass of cells, on the other hand, has only some cells which are able directly to absorb food materials from the water, those cells on the surface. The surface cells constitute the absorbing organ. Under these are other cells, containing chlorophyll, which manufacture the absorbed food materials into foods. If the plant is small, there may be besides only those cells which are used for storing the manufactured product and those concerned with reproduction. If the plant is larger, like the rock weeds and kelps, there must be in addition a system of cells for conducting the foods from the cells manufacturing them to others needing them. In all aquatics, even the largest, unless some are land plants retaining the structures characteristic of land plants even after becoming aquatic, there is only this one system of conducting tissues, the one which distributes food.

As we pass from the submersed aquatics to those only periodically submersed, from these to plants living prostrate on the ground, like most liverworts, and from these to erect plants, we see progressive changes in absorbing and conducting systems. The plants living between the tide-marks, for example the rock weeds and devil's apron (*Laminaria*), possess a conducting system similar to the submersed kelps, but the absorbing system is reduced in extent to prevent the plant from losing water by evaporation while exposed at low tide. In these plants there is need of two sets of qualities, those adapted to life under water, those fitted to life in the air—essentially, enough cells for absorbing water, and enough cells so placed and of such composition as to keep evaporation within safe limits.

The prostrate land plants, for example the liverworts, possess tissues similar to the small though massive algæ living between the tide-marks—an absorbing system and a protective system. But as, for most of the time, the prostrate land plant can absorb water only from the soil underneath it, and lose water by evaporation only from its upper surface, the absorbing and protective systems are

separated, the food-manufacturing tissue lying between the other two. These prostrate plants are all so small that no conducting system is needed.

So soon as a plant turns up into the larger and unoccupied space above the soil, the part which grows up cuts itself off from a direct supply of water and mineral food materials and exposes itself to greater loss by evaporation. The absorbing system of the part still in contact with the soil must be extended, the part above must be covered with material less permeable to water, and a conducting system which will supply the part above with water, which can come only from below, must develop. This we find in the erect mosses, and also in these cells which mechanically support the parts the weight of which is not wholly or directly carried by air and soil. The larger mosses, *Polytrichum* for instance, show these different tissues.

When a plant assumes the erect posture, its structure must correspond with its changed habit. The anatomical changes in man's body, which supposedly took place when he assumed the erect posture, have been explained by zoologists. Similarly there are changes in the bodies of plants which take on the erect habit of growth. These changes enable them to conform to the new relations and degrees of mechanical strains, the different relations to absorption and loss of water, the different relations to light, etc. The simpler, larger, erect plants, for instance the grasses, have worked out the relations of absorbing, protecting, food manufacturing, conducting, and mechanically supporting systems in very definite fashion. In these plants, absorbing and food-manufacturing systems are remote from each other, connected, however, by conducting tissues which carry the mineral salts and water needed for food manufacture, plus the amount of water which must inevitably be lost by evaporation, an amount constantly varying everywhere, but differing greatly according to situation, climate, etc. In these plants there must be the other conducting system, the one for distributing the food made in the leaves to all the living cells in other parts. Here we encounter, as in the ferns and their allies, which might equally well have been selected as illustrating these points, the double conducting system. The food-distributing system is found in all larger plants in which there are other living cells than those engaged in food manufacture. This is the primitive conducting system, the one first needed, as our consideration of the larger aquatics showed. Only when absorbing and food-manufacturing tissues are remote from each other is another conducting system needed and developed, and the dimensions of this correspond with the volume of water to be carried to supply food materials and to make good the loss by evaporation.

In the ferns and their allies, and in the grasses, the tissues mechanically supporting the parts above ground are combined into what may be called an external skeleton. This is distinct from the conducting tissues. It forms a cylinder close under the epidermis and enclosing the conducting and storing tissues. Each strand of conducting tissue may also be inclosed in a strengthening cylinder. This kind of skeleton is strong for the weight and amount of material in it, but it has the serious disadvantage of limiting the size of the organ or organism. The lobster and crab can continue to grow only by splitting the external skeleton. They shed this periodically, forming a new and larger one. Till this is formed they are weak and defenseless. If an erect plant were to split its external skeleton it would be too weak to stand. The limit which it sets to the size of the plant, rather than the difficulty of branching which is sometimes alleged as the disadvantage, is the serious defect in an external skeleton.

The grasses show an approach to an internal skeleton in that the greater part of the strength of the stem is due to the cylinders of supporting tissue in which the strands of conducting tissue are enclosed. But if the whole plant were to continue to grow, the cylinders in which the conducting tissues are enclosed would have to increase in diameter to allow an increase in the conducting tissues and this can not be done without splitting the strengthening cylinders and thereby greatly weakening the whole plant.

In the pines (using the word broadly) support and the conduction of liquids are accomplished by the same tissues, the same cells. These are the lowest plants in which an internal skeleton, if I may call it so, is found. Such a skeleton sets no limit to growth. It can be added to year by year as there is need of increased strength, and at the same time increased conducting tissue is formed. But conduction and mechanical support can not both be attained with the utmost efficiency and economy of material in cells which must serve both purposes. The diameter of the conducting elements must be limited lest they be weak, they must be comparatively short for the same reason, there can be no continuous tubes through which liquids can be rapidly transported. To ensure the requisite mechanical strength to the whole plant, the walls of the conducting cells must be thicker than would otherwise be necessary.

In the highest flowering plants, the dicotyledons, conducting and mechanically supporting tissues are combined in the same strands, but the same cells do not serve both purposes. In these plants, conducting and strengthening cells are side by side, they increase in number according to the needs of the plant, the conducting cells most rapidly when most needed—as in the early spring—the strengthening cells later, when the increasing weight of the growing parts

makes increased support necessary. In this combination of conducting and strengthening tissues, with the distribution of the two functions among different cells, the highest efficiency with the greatest economy of material is possible. There is no limit to which the plant can increase in size, provided only it preserve, from year to year, a layer of reproductive cells (the cambium) from which new cells developing into new conducting and strengthening elements may be formed.

In comparing the conditions under which water and land plants live this must be added. In the water, conditions change slowly and in regularly recurring periods. On land they change not only in regularly recurring periods but also frequently and suddenly. Submersed aquatics fall into a smaller number of species than do the plants living between the tide-marks. These again are numbered in fewer species than are land plants. The vertical distribution of aquatics is limited by the light to a few feet; the vertical distribution of land plants is limited by the temperature to a few thousand feet. Within this greater vertical space there is far greater diversity of conditions than in the shallow layer of water in which plants can live. This greater diversity of environment has been the cause of the greater diversity among land plants. But land and water plants, were they not sensitive to all the influences which combined make their environments, and had they not reacted to these influences, would never have attained the diversity which they now possess. The dependence of all living things upon water, and their power of reacting to all the influences of their environment to which they are sensitive, are the most striking phenomena displayed by animals and plants.

THE PRESERVATION OF WILD FLOWERS.

BY FRANCES ZIRNGIEBEL,
ROXBURY, MASS.

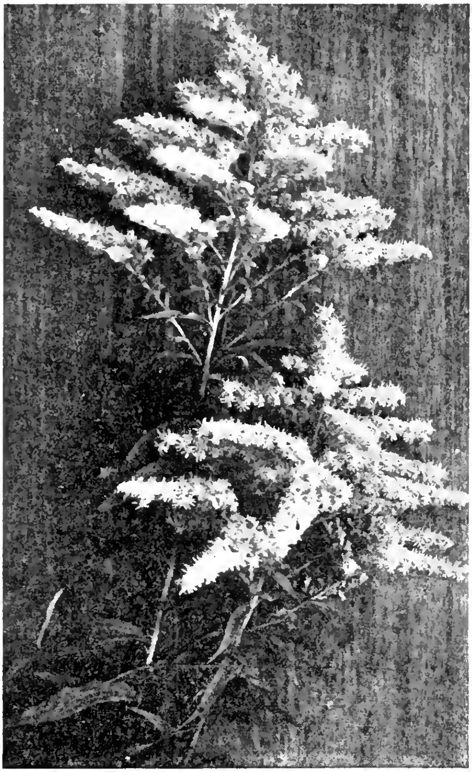
THE fact that several of our delicate and most beautiful wild flowers are fast disappearing from places where they were once found has led to an effort to prevent the complete extermination of certain species and the increasing scarcity of other plants. The plants so endangered differ in different localities. The endeavor to protect particular ones has therefore local modifications, but the basis of the movement, the desire to prevent wasteful destruction of plant life, is the same in all sections of the country.

A national society, known as 'The Wild Flower Preservation Society of America,' has been organized, aiming to do for the native plants what the Audubon Society has so well done for the birds. Its methods of work are similar to those of the bird society. In its official organ, *The Plant World,* has been published during the past year a series of articles on the general subject of plant preservation with the addition of specific suggestions regarding the flowers about New York city. Reprints of these articles may be obtained upon application to the secretary of the society, C. L. Pollard, 1854 Fifth Street, Washington, D. C. A number of persons in New England who take keen interest in wild flowers have united to form a 'Society for the Protection of Native Plants.' The object of this society is to try to do something to check the wholesale destruction to which our native plants are exposed. Brief appeals, to the general public, to children and to nature study teachers have beeen issued and widely distributed in the form of leaflets, which can be obtained of Miss Maria Carter, Boston Society of Natural History. In the state of Connecticut laws have been passed which protect the Hartford fern, and governing boards of various metropolitan reservations of field and woodland have made restrictions regarding the picking of their flora.

The problem presented to the various organizations interested in plant preservation is how depredations may be checked without seriously restricting the freedom or enjoyment of the nature lover. It is desired to set at work such factors as will arouse a healthy public sentiment against indiscriminate and thoughtless flower picking.

The work is much more difficult than that which was before the Audubon Society, and the right public sentiment can not be created in the same manner. Many of the strongest reasons given for bird

protection are wanting in an appeal for the plants. Birds, high in the scale of animal life, with power to feel pain and pleasure, with food-seeking, home-making and young-protecting instincts, demand, as fellow creatures, freedom from cruelty. Efforts were first made to protect them as individuals, while the prevention of the destruction of species was a secondary consideration. Through the agricultural department of our government, knowledge of the great economic value of birds was disseminated, and this was a most effective means of in-

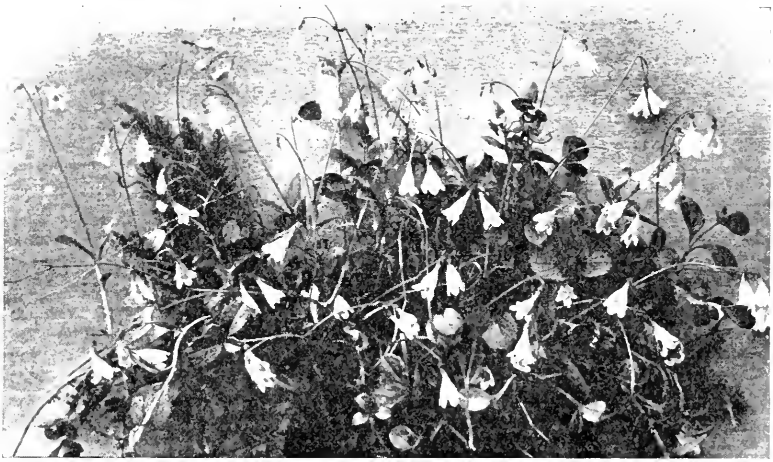


GOLDEN-ROD (*Solidago serotina*).

suring their protection. Through the same department people learned of the vast value of our trees to preserve which a public sentiment was created. Laws were then passed for their protection, and we now have a distinct forestry policy.

To most persons our wild plants are only things of beauty, common property to be admired or destroyed at will and, therefore, can not be preserved by the same petitions as were made in behalf of the birds. The appeal for the plants is much more difficult and must be at first

not a thoughtfulness for the plant, less it degenerate into an unhealthy sentiment, but a request that consideration be given to the rights of other people, that common property be protected for com-



TWINFLOWER (*Linnæa borealis*).

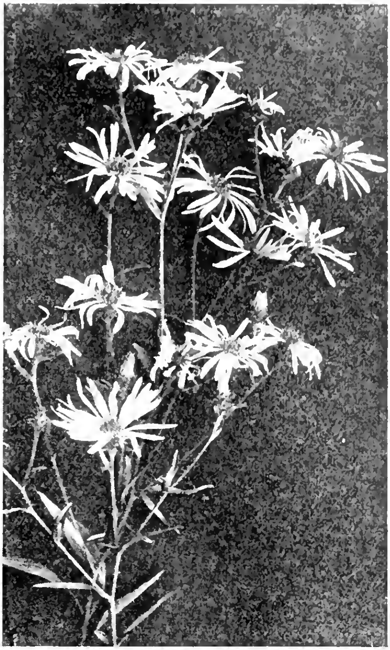
mon enjoyment. Efforts to create reforms through calling upon higher altruistic motives require a long time for their process of evolu-

GREAT LAUREL (*Rhododendron maximum*).

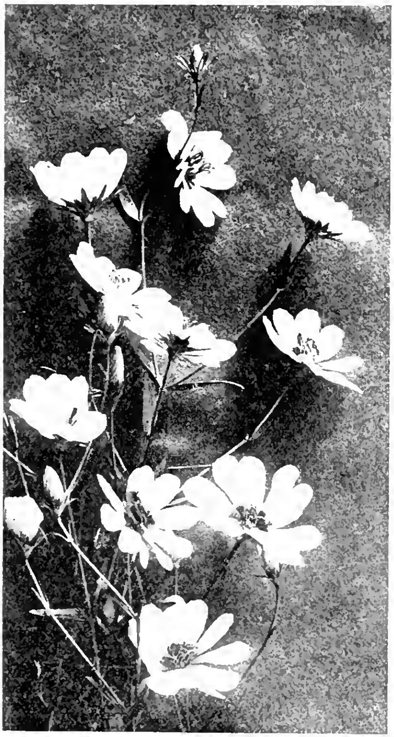
tion, and demand most strenuous work in order that the 'influence of the enlightened few' may be felt by the 'unenlightened many.' Permanent reform is best assured by positive rather than negative means,

and this particular one can be easily, though slowly, accomplished through nature study.

The increasing interest in the study of nature and the publication of numerous illustrated popular books on the subject have been much feared by the friends of the wild flowers, who feel that wanton destruction will follow in the path of the enthusiastic young student. This fear has been somewhat justified in towns and cities where, in their eagerness to get specimens for the class, the thoughtless pupils have robbed the parks and gardens. Perhaps, too, in the country, the nature study program has been the means of reducing the numbers of our most attractive wild flowers. This was a natural result of the first step in a movement which will develop into a more carefully directed study. The popular teaching of ornithology in America has advanced farther than botany. In its early days collecting 'sets of eggs' and skins of birds were prominent features of the work and the extinction of the great auk was one of the results. But now, partly through nature study and partly through the influence of the Audubon Society, studying the habits of birds, naming them without a gun, photographing eggs in the nest and birds in the bush are the most popular aspects of the study.

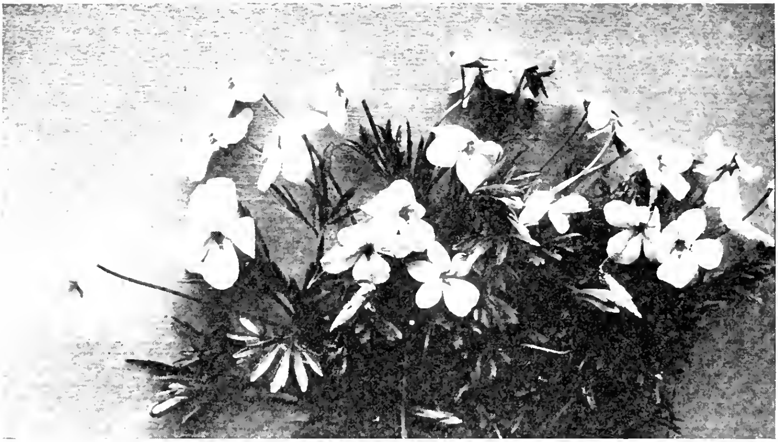


ASTER (*A. spectabilis*).



SABBATIA (*S. stellaris*).

The gathering of plants to be used in schools as specimens for class instruction can be obviated by school authorities arranging to purchase such supplies from botanic gardens or nurseries where they have been



BIRD-FOOT VIOLET (*Viola pedata*).

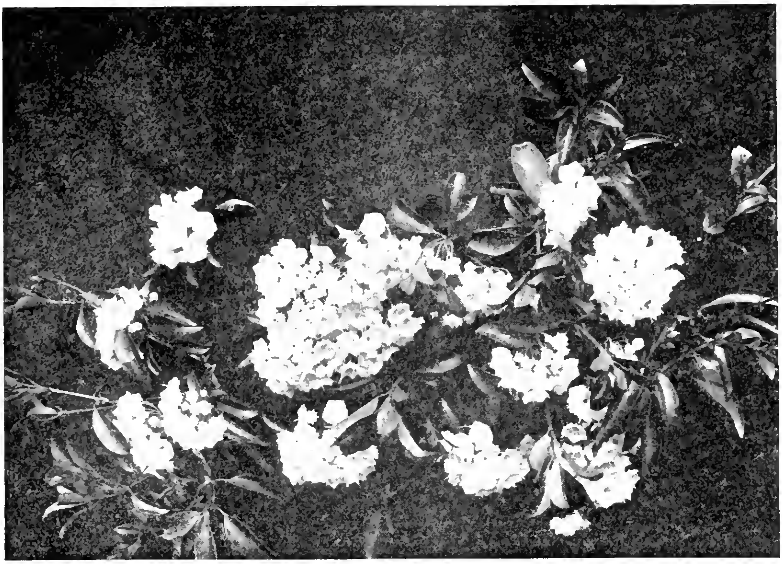
raised in large numbers for the purpose. Such an arrangement has been made between a few teachers of botany in Boston, and the

PLYMOUTH MAYFLOWER, TRAILING ARBUTUS (*Epigæa repens*).

directors of the Bussey Institute of Harvard University. Well might a portion of city parks and public gardens be devoted to the raising of such plants as are in demand for botanical instruction. The farmer's

boy or girl, having at his disposal various kinds of land and being able to gain intimate knowledge of the conditions best suited to the different wild flowers which would not flourish in a city park, can experiment with their cultivation, and in time find the raising of native plants a useful and fascinating employment. The instilling of a love of flowers will help to protect them, but this must be united with scientific knowledge of their structure and relation to their environment in order that the necessity for restricting the manner in which they are gathered and the number that are collected will be evident.

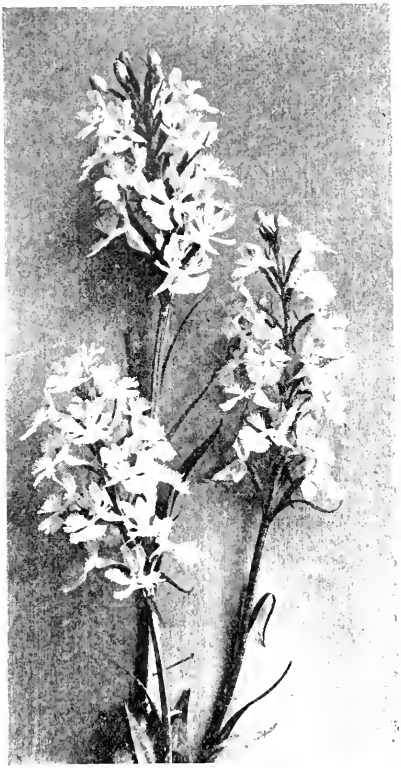
The epigæa perhaps has suffered more from inroads upon it than any other New England plant. Its sweet odor and delicate beauty



Mountain Laurel (*Kalmia latifolia*).

were in themselves attractive. Its connection with the Plymouth settlement created for it a patriotic sentiment which unfortunately was not united with a knowledge of the office of its underground rootstock and its slow manner of growth. Bryant's poem drew to the fringed gentian the attention of those who never knew before of its intrinsic beauty and interesting botanical structure. It is now being gathered for flower markets and becoming scarcer in meadows.

The epigæa, the gentian and other fast disappearing flowers, though difficult of cultivation, should be choicely guarded in wild flower reservations, which should be to the plants of America what the large country estates are to those of England. The Sharon Biological



Purple Fringed-orchis (*Habenaria psycodes*).

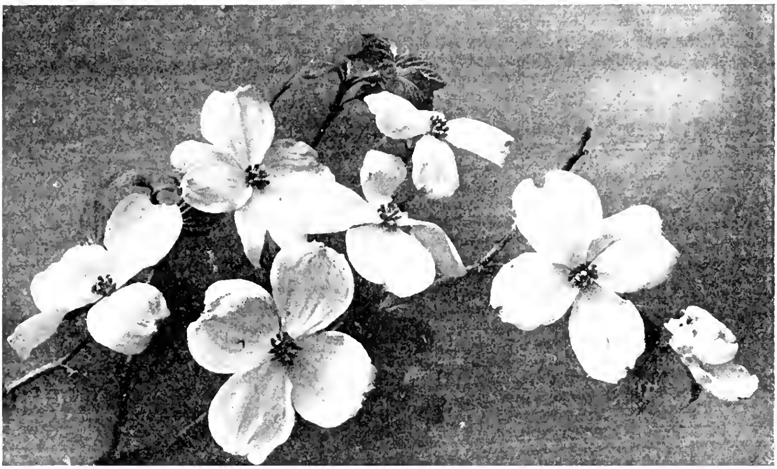
Observatory controls three hundred acres of land in Massachusetts which serves as a preserve for native plants and animals. All the deciduous trees of the state and also the native flowering plants are now growing there under protection. As people become more and more devoted to nature study; when they see how much more beautiful the plants are in their haunts than in a wilted bouquet; when they gain more knowledge of botany and know the plants intimately, learning in what ways they struggle for existence; they will not need to be asked not to destroy the plants needlessly, but will unite themselves with the 'enlightened few' until they become the enlightened many. Then the gentian, the sabbatia, the epigæa, the orchids and other delicate plants, ill fitted to struggle for existence, but not necessarily unworthy to survive, will be protected and mutual aid will become a factor in their evolution.

Swamp Rose-mallow (*Hibiscus Moscheutos*).

Plant preservation depends partly upon the natural adaptation of plants to their environment and partly upon the attitude of people toward them. The very absence of beauty in some plants

renders them unlikely to be destroyed by too much picking, while the strikingly beautiful ones fall prey to thoughtless collectors. Others, on account of their protective coloration, escape the notice of wild flower gatherers or browsing cattle. The disagreeable odor of the skunk cabbage, the bitter taste of the crowfoots, the poisonous properties of various members of the parsley and nightshade families, and the stinging glands of the nettles prevent animals from repeating unpleasant experiences with them.

The power to produce, through a long season, many flowers, bearing many seeds, well adapted for dissemination and germination, under ordinary conditions, is the height of plant differentiation for preservation of species. A consideration of some New England wild

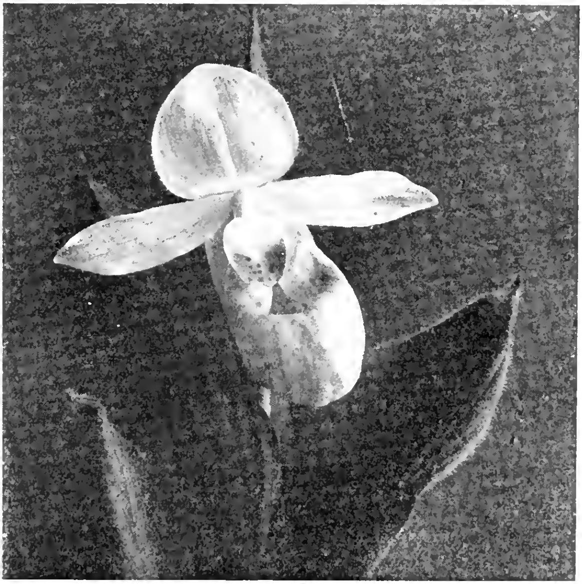


FLOWERING DOGWOOD (*Cornus florida*).

flowers will serve as specific illustrations of the way in which plants are self protected and the reasons why they require other aid in order that preservation may be insured.

In the early days of April the bloodroot pushes itself through the ground, each flower-bud rolled in a green leaf. The leaf unrolls somewhat; the flower pushes itself through it up into the air. The delicate calyx drops off and the corolla of pure white petals spreads itself out surrounding a cluster of golden yellow stamens, in the center of which is the pistil. After a few days the stamens wither up, the petals drop off and the pistil, if fertilized, remains, growing larger and larger until the ovules within it are matured. Then the work of the plant, along the line of perpetuation of its kind, is over for a year. The unfolded leaves expand more and more on their lengthened petioles and spread themselves out into the light and air. They then continue

to act as organs of great activity in the vegetative work of the plant. Through them carbon dioxide and oxygen are taken in from the air and united, in the green cells, with water and nitrogenous matter absorbed from the soil by the root hairs. The carbon dioxide and water unite to form carbohydrates such a starch and sugar, and oxygen which is given off as a waste product. The carbohydrates and other food products, proteids manufactured in the leaves, are transported to regions of growth, such as buds, or places of storage, like underground stems. Before being transported to growing points, the insoluble products are digested or changed to soluble forms, starch being changed to sugar and then transformed into various plant tissues. If carried to storage regions they are first converted back into insoluble forms,



SHOWY LADY'S SLIPPER (*Cypripedium spectabile*).

such as starch, and then stored up to supply energy for the rapid development of the next spring.

Picking the flowers of the bloodroot destroys the only possible chance of those particular flowers producing seed which may be able to survive and reproduce their kind. Destroying the leaves or the rootstock interferes with subsequent growth of the plant.

Herbaceous perennials, that is soft-stemmed plants which live on and produce flowers season after season, die down to the ground each fall and in the spring send forth shoots from the buds which are just under the surface. Those which blossom earliest have the largest

underground storehouses. The solomon's seal, ginseng, anemone, violet, bellwort, trillium and iris have underground rootstocks which provide energy for rapid development in the spring. The adder's tongue and other lilies, the claytonia or spring beauty, and the jack-in-the-pulpit have bulbs or corms deep down in the ground which serve as storehouses for plant food. They send up in the spring a few comparatively large leaves and a single scape of flowers which can be picked without doing much damage to the plant itself. The jack-in-the-pulpit, however, grows in moist soil and is easily uprooted. The mayflower (epigæa), and the twin-flower (linnæa) both have slender, rather woody creeping rootstocks which are frequently torn up when the blossoms are broken off rather than cut off.

The late blooming perennials suffer less by picking than those plants which blossom earlier, for their vegetative work for the season is nearly completed when they become attractive and subject to injury. The woody perennials, shrubs and trees, form buds in the axils of their leaves and at tips of branches. The buds increase in size during the summer and the next spring become swollen as the sap from the stem rises in them. Then they burst open and develop into new branches bearing leaves and flowers. If the twigs are broken off the growth of several years and also the buds, promises of new branches, are destroyed. The rhododendron, magnolia, mountain laurel, flowering dogwood and other attractive early blooming shrubs suffer in this way. The gathering of mountain laurel for winter decorations destroys quantities of buds which would have developed into beautiful clusters of blossoms in the early summer. Careful cutting or pruning of a shrub or tree is nevertheless advantageous to it, checking an over exertion on the part of the plant, which is necessary to flower production, and thereby strengthening the parts which remain.

Annuals are herbaceous plants which live but one year, dying after the maturing of the seed. Their only means of perpetuating their race is through the production of seed. Wholesale plucking of their blossoms will, therefore, lead to their extermination. The fringed gentian, and the pink sabbatia are among these plants. They are very difficult to transplant and local in distribution. The painted cup, known in the west by the better name of painter's brush, is also an annual, and exhibits a sign of weakness in parasiticism of its roots. These plants call for special protection. Careful cutting of few blossoms from the portions of a plant where they are thickest is often a benefit to the flowers which remain, giving them additional energy for the production of fruit which is more exhausting to the plant than production of flowers.

Notwithstanding the inroads that are made upon violets they thrive and increase in numbers. One reason for this is that they have hidden underground flowers which do not open, but in which self-pollination is effected and seed produced, giving the violet an extra means of reproducing its kind. The fringed polygala is also provided with these hidden flowers. Many of the so-called weeds, plants which have been accidentally introduced into this country, are so well fitted for the struggle for existence that they have successfully combated against unnatural environment and have increased enormously in numbers and geographical distribution. Many of these, as the daisy (white weed), chickory, dandelion and the thistle, as well as the native golden rods and asters, are members of the compositæ family. This group is represented by over 10,000 species, comprising one tenth of all the seed plants, each represented by many individuals of a wide range. This family of plants is the most highly differentiated. Numbers of small flowers are arranged in compact heads or clusters, presenting a complete organization in which there is a division of labor among the members of a head. They present various contrivances for cross-pollination and various adaptations of the calyx into agents for seed dissemination.

In the early summer the fields are white with daisies, which later are replaced by the golden rods. Their

> Midas touch hath turned the land to gold
> For us to have and hold.

Quantities of golden rod, as well as daisies, asters, golden-ragwort, chicory, fleabane and rudbeckia can be gathered without causing any serious reduction in their numbers. The desire to possess armfuls of flowers is thereby gratified, as is also the farmer who counts these plants as pests.

AN UNTILLED FIELD IN AMERICAN AGRICULTURAL EDUCATION.

BY KENYON L. BUTTERFIELD.

AGRICULTURAL education in this country has thus far been an attempt to apply a knowledge of the laws of the so-called 'natural' sciences to the practical operations of the farm. Comparatively little attention has been paid to the application of the principles of the 'social' sciences to the life of the farmer. All this is partly explained by the fact that the natural sciences were fairly well developed when the needs of the farmer called the scientist to work with and for the man behind the plow—when a vanishing soil fertility summoned the chemist to the service of the grain grower, when the improvement of breeds of stock and races of plants began to appeal to the biologist. Moreover, these practical applications of the physical and biological sciences are, and always will be, a fundamental necessity in the agricultural question.

But in the farm problem we cannot afford to ignore the economic and sociological phases. While it may be true that the practical success of the individual farmer depends largely upon his business sense and his technical education, it is folly to hope that the success of agriculture as an industry and the influence of farmers as a class can be based solely upon the ability of each farmer to raise a big crop and to sell it to advantage. General intelligence, appreciation of the trend of economic and social forces, capacity to cooperate, ability to voice his needs and his rights, are just as vital acquirements for the farmer as knowing how to make two blades of grass grow where but one grew before. It finally comes to this, that the American farmer is obliged to study the questions that confront him as a member of the industrial order and as a factor in the social and political life of the nation, with as much zeal and understanding as he is expected to show in the study of those natural laws governing the soil and the crops and the animals that he owns.

In this connection it is significant to note that farmers themselves are already quite as interested in the social problems of their particular calling and in the general economic and political questions of the day, as they are in science applied to their business of tilling the soil. Not necessarily that they minimize the latter, but they seem instinctively to recognize that social forces may work them ill or work them good according to the direction and power of those forces. This statement

is illustrated by the fact that the aims, purposes, labors and discussions of the great farmers' organizations like the Grange are social in character, having to do with questions that are political, economic, sociological.

When, however, we turn to those public educational agencies that are intended to assist in the solution of the farm problem, we discover that they are giving slight attention to the social side of the question. An examination of the catalogues of the agricultural colleges, whether separate institutions or colleges of state universities, reveals the fact that, beyond elementary work in economics, in civics, and occasionally in sociology, little opportunity is given students to study the farm question from its social standpoint. With a few exceptions, these institutions offer no courses whatever in rural social problems, and even in these exceptional cases the work offered is hardly commensurate with the importance of the subject. Nearly all our other colleges and universities are subject to the same comment. The average student of problems in economics and sociology and education gains no conception whatever of the importance and character of the rural phases of our industrial and social life.

It may be urged in explanation of this state of affairs that the liberal study of the social sciences, and especially any large attention to the practical problems of economics and sociology, in our colleges and universities is a comparatively recent thing. This is true and is a good excuse. But it does not offer a reason why the social phases of agriculture should be longer neglected. The purpose of this article is less to criticize than to describe a situation and to urge the timeliness of the large development, in the near future, of rural social science.

At the outset the queries may arise, What is meant by rural social science? And, What is there to be investigated and taught under such a head? The answer to the first query has already been intimated. Rural social science is the application of the principles of the social sciences, especially of economics and sociology, to the problems that confront the American farmer. The reply to the second query is not designed as an outline of all the courses that may be offered, but merely as a concrete illustration of work that could be followed by investigators and teachers, and by them indefinitely expanded.

Taking first those subjects that have an economic bearing, we may suggest agricultural geography: the relation of soil and climate to agriculture, agricultural resources, the natural and actual distribution of crop-growing, relation of science to agriculture, etc.—The farmer's market: including, besides a general discussion of the subject, a consideration of the special features of the local market, the domestic market and the foreign market. Also, a brief discussion of special influences affecting the farmer's market, such as the tariff, export duties, bounties, dealings in 'futures,' crises, the development of manu-

facturing, etc.—Questions like the relation of transportation, of industrial concentration, and of taxation, to agriculture.—Business cooperation among farmers.—Exchange facilities in rural districts.—Tenant farming.—Large *vs.* small farming.—Machinery and agriculture.—History of the farming industry.

Considering now themes that are more purely sociological, we may name rural education, including first, the rural schools proper and second, agricultural education especially. Under the latter head could be discussed nature-study teaching in rural schools, agricultural schools and colleges, experiment station work, agricultural fairs, farmers' institutes.—Rural religious institutions.—Farmers' organizations: the Grange, farmers' clubs, farmers' alliances.—Rural communication: wagon roads, trolley lines, telephones, rural mail delivery.—Degeneracy, pauperism, intemperance, crime, in rural life.—Social life in the country.—Arts and crafts in rural communities.—Rural social psychology.—Social history of agriculture.

These lists are purely suggestive and by no means complete. There are also subjects that have a political bearing, such as local government in the country, and primary reform in rural communities, which perhaps ought not to be omitted. So too, various phases of home life and of art might be touched upon. The subjects suggested and others like them could be conveniently grouped into from two to a dozen courses, as circumstances might require.

What classes of people may be expected to welcome and profit by instruction of this character? (1) The farmers themselves. Assuming that our agricultural colleges are designed, among other functions, to train men and women to become influential farmers, no argument is necessary to show how studies in rural social science may help qualify these students for genuine leadership of their class of toilers. On the other hand, it may be remarked that no subjects will better lend themselves to college extension work than those named above. Lectures and lecture courses for granges, farmers' clubs, farmers' institutes, etc., on such themes would arouse the greatest interest. Correspondence and home study courses along these lines would be fully as popular as those treating of soils and crops. (2) Agricultural educators. The soil physicist or the agricultural chemist will not be a less valuable specialist in his own line, and he certainly will be a more useful member of the faculty of an agricultural college, if he has an appreciative knowledge of the farmer's social and economic status. This is even more true of men called to administer agricultural education in any of its phases. (3) Rural school administrators and the more progressive rural teachers. The country school can never become truly a social and intellectual center of the community until the rural educators understand the social environment of the farmer. (4) Country clergymen. The vision of a social service church in the country will remain but a

dream unless, added to the possession of a heart for such work, the clergyman knows the farm problem sufficiently to appreciate the broader phases of the industrial and social life of his people. (5) Editors of farm papers, and of the so-called 'country' papers. Probably the editors of the better class of agricultural papers are less in need of instruction such as that suggested than is almost any one else. Yet the same arguments that now lead many young men aspiring to this class of journalism to regard a course in scientific agriculture as a vestibule to their work, may well be used in urging a study of rural social science, especially at a time when social and economic problems are pressing upon the farmer. As for the country papers, the work of purveying local gossip and stirring the party kettle too often obscures the tremendous possibilities for a high class service to the rural community which such papers may render. No men, in the agricultural states at least, have more real influence in their community than the trained, clean, manly, country editors—and there is a multitude of such men. If as a class they possessed also a wider appreciation of the farmer's industrial difficulties and needs, hardly any one could give better service to the solution of the farm problem than could they. (6) Everybody else! That is to say, the agricultural question is big enough and important enough to be understood by educated people. The farmers are half our people. Farming is the largest single industrial interest in the country. The capital invested in agriculture is four fifths the capital invested in manufacturing and railway transportation combined. Whether an individual has a special interest in business, in economics, in education, or in religious institutions, he ought to know the place of the farm and the farmer in that question. No one can have a full appreciation of the social and industrial life of the American people who is ignorant of the agricultural status.

The natural place to begin work in rural social science is the agricultural college. Future farmers and teachers of farmers are supposed to be there. The subjects embraced are as important in solving the farm problem as are biology, physics or chemistry. No skilled farmer or leader of farmers should be without some reasonably correct notions of the principles that determine the position of agriculture in the industrial world. A brief study of the elements of political economy, of sociology, of civics, is not enough; no more than the study of the elements of botany, of chemistry and of zoology is enough. The specific problems of the farmer that are economic need elucidation alongside the study of soils and crops, of plant- and stock-breeding. And these economic topics should be thoroughly treated by men trained in social science, and not incidentally by men whose chief interest is technical agriculture.

The normal schools may well discuss the propriety of adding one or

two courses which bear on the social and economic situation of the rural classes. While these schools do not now send out many teachers into rural schools, they may do so under the system of centralized schools; and in any event they furnish rural school administrators, as well as instructors of rural teachers. There seems to be a growing sentiment which demands of the school and of the teacher a closer touch with life as it is actually lived. How can rural teachers learn to appreciate the social function of the rural school, except they be taught?

Nor is there any reason why the theological seminaries, or at least the institutions that prepare the men who become country clergymen, should not cover some of the subjects suggested. If the ambition of some people to see the country church a social and intellectual center is to be realized, the minister must know the rural problem broadly. The same arguments that impel the city pastor to become somewhat familiar with the economic, social and civic questions of the day hold with equal force when applied to the necessary preparation for the rural ministry.

The universities may be called upon to train teachers and investigators in rural social science for service in agricultural colleges, normal schools and theological seminaries. Moreover, there is no good reason why any college or university graduate should not know more than he does about the farm problem. There can be little doubt that the interest in the farm question is very rapidly growing, and that the universities will be but meeting a demand if they begin very soon to offer courses in rural social science.

The arguments for rural social science rest, let us observe, not only upon its direct value to the farmers themselves, but upon its necessity as a basis for that intelligent social service which preacher, teacher and editor may render the farming class. It is an essential underlying condition for the successful federation of rural social forces. Indeed it should in some degree be a part of the equipment of every educated person.

It may not be out of place to add, in conclusion, that instruction in rural social problems should be placed in the hands of men who are thoroughly trained in social science as well as accurate, experienced and sympathetic observers of rural conditions. It would be mischievous indeed if in the desire to be progressive any educational institution should offer courses in rural social science which gave superficial or erroneous ideas about the scientific principles involved, or which encouraged in any degree whatever the notion that the farmer's business and welfare are not vitally and forever bound up with the business and welfare of all other classes.

THE STORY OF ENGLISH EDUCATION.

By J. E. G. DE MONTMORENCY, B.A., LL.B. (Cantab.),
BARRISTER-AT-LAW.

THE history of education in England is a subject of profound interest and of singular importance; for it is intimately associated with all the great crises of the national life, and exhibits, as no other subject can, the effects of the interplay of religion, learning and politics upon the sociological development of a great people. The subject is, moreover, one that belongs to all the daughter-nations of England, whether, like Canada, they are still, to use a simile from Roman law, within the English *manus*, or whether, like the United States, they have become *sui juris*. For it is necessary to go back far in time if we would trace with honesty the obscure streams of thought, learning and tendency that are responsible for the great systems of education in force in the various parts of the English-speaking world to-day. We have indeed to go back to times which are the common property of that world, and delve among the records of fifteen hundred years of strife and effort if we would understand the meaning and the direction of modern education as conceived by the Anglo-Saxon race. It is well sometimes to dwell, if only for a moment, on the permanence, the persistence, the soundness of the social forces that through a millennium and a half have emanated and still emanate from Britain. Fifteen hundred years almost exactly measured the period of the great Roman race from Romulus the first king to Romulus the last emperor. The Anglo-Saxon race at the end of a similar period shows little sign of exhaustion. It has, as we are often reminded by reformers of every possible type, faults and vices enough; but in the main they are the vices and faults of youth—of youth somewhat impatiently and curiously approaching adolescence after an infancy of fifteen centuries. I desire in these pages briefly to consider this infancy and to indicate the main educational lines that have been followed in so vast a period of preparation. To do so will, I believe, be valuable, for, in the storm and stress of modern times, men are perhaps a little apt to neglect the principles of progress that have been wrung, at the cost of infinite tears, from nature in the past—principles that are the motives of history if we will but read it.

We know from the writings of Tertullian and Origen that it is now at least seventeen hundred years since christianity took root in Britain; while Zozomen and Eusebius reveal to us, in the fourth

century of our era, a complete and organized British church, holding the catholic faith, represented at the great church councils, and in intercourse with Palestine and Rome. This early church undoubtedly possessed and disseminated some measure of culture in the Isle, and when the first contact with the See of Rome came, that culture was certainly broadened, though from first to last during the Saxon period the spiritual control of Rome was specifically rejected. Augustine, the first Archbishop of Canterbury, came to Britain in 596 A. D., and to him in the year 601 A. D. Pope Gregory committed the charge of 'the Bishops of the British.' The church as reorganized by Augustine and his followers maintained the old independence, and when Theodore of Tarsus, a successor of Augustine in the See of Canterbury, deposed Wilfrid, Bishop of York, Pope Agatho was unable to compel either king or archbishop to restore him to his seat. This Theodore of Tarsus is one of the earliest names in English education. He and the Abbot Adrian, about the year 668 A. D., brought to England new means and methods of education. They made each of the greater monasteries an educational center, and it is certain that in this dark age Greek itself was taught to those who would learn. Indeed, the first important period of English culture was at hand. Bede tells us in his 'Ecclesiastical History' (Vol. IV., C. II.) that in the year 732 A. D. there were living in England disciples of Theodore and Adrian, who knew the Greek and Latin tongues as well as their own language. The use of Latin became indeed so usual that Bede speaks of it as 'the vernacular': 'The Creed and the Our Father I have myself translated into English for the benefit of those priests who are not familiar with the vernacular.' He himself taught in the monastery school at Jarrow, and wrote small treatises on the Trivium and Quadrivium for use in monastic schools. Alcuin was born into this first spring of learning in the year 735 A. D., and he boasts of the learned men and noble libraries of England. Charlemagne did all that he could to benefit by the scholarship that existed in our island, and in securing the services of Alcuin he initiated that earliest movement of Gallic culture which resulted in the creation later of the University of Paris. The first English period died away all too soon. "The sloth of the priesthood, the unrest of the land, the red ruin of the Dane, killed it south to north, and when Alfred came all that was left were some stray vestiges of scholarship in far Northumbria." The age was dark indeed, and despite the remarkable efforts made by the church of Rome in the ninth century for the extension of learning and the founding of schools,* little could be done. Alfred did what could be done. He

* See the Canon *de scholis reparandis pro studio literarum* promulgated at the Concilium Romanum in 826 A. D., in the time of Pope Eugenius II. This canon appears to be little known to educationists. It should be read in connec-

founded and endowed with an eighth of his income a school mainly for the children of his nobility. Possibly, however, even serfs could attend this school. He also secured the freedom from tribute of the Saxon school in Rome. From this time forward we find that steady educational progress can be noted. King Ethelstan, by a law of 926 A. D., bestowed certain special benefits on learned clergy and thus founded the doctrine of 'Privilege of Clergy'—the right of a person (lay or clerical), who could read, to special rights in relation to the criminal law. This privilege in the middle ages certainly aided the spread of learning and though, when abolished in England in 1826, it had long outgrown all meaning and even all harmfulness, its importance as an educational factor must not be forgotten.*

The development of education from the ninth century onwards was in the hands of the national church for many generations. It was the practice, both in England and in France, from the end of the eighth century, for the mass-priests to hold at their houses schools for young children and, at any rate from the tenth century, it was usual for parents to pay school fees. The Church of England by thus creating an elaborate educational system rapidly established a new claim to the possession of a national character. With the coming of the Normans in 1066 and the sudden increase of papal influence, we might expect to find, as we do find, the bishops speaking on educational questions in an authoritative manner. Rome realized the importance of exercising control over schools, and of fostering their increase, and she developed this policy in spite of the stern anti-Roman position eventually exhibited by William I. We must note here two canons on the question of education which, though promulgated at national synods sitting at Westminster, really emanated from Rome. Canon XVII. of 1138 A. D. ordained that schoolmasters should not, under penalty of ecclesiastical punishment, 'hire out' their schools. This canon made for efficiency. The man who took the fees must teach the school. Canon VIII. of the year 1200 ordained that nothing should be exacted by the church from schoolmasters in return for the license to teach. This canon shows how widespread was church control over education in the opening of the thirteenth century. This power of granting licenses to teach created a valuable and valued monopoly, and local records (such as the records of Beverley Minster) prove that many a stern fight took place between licensed and unlicensed schoolmasters for the lucrative right of instructing youth, and that on occasions the secular and spiritual courts came into col-

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tion with decrees of the third Council of Lateran (1179 A. D.), the fourth Council of Lateran (1215 A. D.) and the Council of Vienne (1311 A. D.).

*I believe that benefit of clergy still nominally exists in some states of the Union.

lision on the subject. The crown, moreover, as in the Ferendon schools case, decided in 1344, absolutely declined to admit ecclesiastical patronage over the grammar schools of England. From about this same date the absolutism of the church over education was threatened in various directions.

The 'Black-Death' of 1348–9 had the result of driving foreign priests from the land. After the terrible ravages of the dread pestilence had been smoothed away by the hand of time, we find that one of the lasting economic results was the fact that priests of English birth and speech served the churches and schools. We know this from contemporary documents. John de Trevisa tells us that immediately after the 'Black Death' John Cornwaile, master of grammar, 'chaunged the lore in gramer scole and construccioun of Frensche in to Englische'; and by the year 1385 'in alle the gramere scoles of Engelond, children leueth Frensche and construeth and lerneth an Englische.' The influence of Rome was diminished by the growth of a purely national English priesthood. At this very time the Lollard movement dealt a new blow at papal power. John Wyclif entirely repudiated Roman Catholicism, and his ideas rapidly permeated the country. Many Lollard schools were founded, while great and successful efforts were made by Wyclif's followers to protestantize the existing grammar and parochial schools. The revolt was so effective that by statute in 1401 and by the constitutions of Archbishop Clarendon in 1408, Lollard schools and Lollard schoolmasters were suppressed with violence, and for the space of some fifty years were apparently exterminated. In the meantime the Commons, possibly through fear of Rome or of Lollardy, or both, determined if possible to stop the spread of education among the unfree classes. The Articles of Clarendon more than two centuries before had forbidden villeins to become clerks without the permission of their lord and special manorial customs to the same effect were not unusual. The Commons determined to strengthen if possible these old feudal customs—originally designed to preserve for the lord of the manor the labor of his hind—and in 1391 petitioned King Richard II. to ordain and command that henceforward no neif or villein should send his children to the schools for the purpose of enabling them to alter their social status by the acquisition of 'clergy.' Such a retrograde movement was impossible. Even in the twelfth century the serf had been able to struggle by means of education into a higher class,* and it was impossible now to close the door. The king, therefore, and boldly, rejected the petition, and in a few years the first statute of education, setting forth the right of man to education, became law. This act, passed in 1406 (7. Hen. IV. c. 17), declared that 'every man or woman, of what state or con-

* See the *de nugis curialium* (Distinc. 1, Cap. X.), by Walter Map (fl. 1180 A. D.).

dition that he be, shall be free to set their son or daughter to take learning at any school that pleaseth them within the realm.' This great step was reached just five hundred years ago. The universal right of all, bond or free, to education was placed on a firm and unalterable basis. Until that was done it would have been hopeless for the 'New Learning,' for the Renaissance, to take root in England. Great movements take hold, not of individuals but of nations, and unless this nation had been free and fit to learn it never could have received the new life of the spiritual movement, which, beginning with the work of Wyclif, concluded with the ironies of the political reformation under Henry VIII. The tremendous though futile efforts made by Robert Grossteste, Bishop of Lincoln, Roger Bacon, and their school to introduce the awakening culture of the thirteenth century into England proved that the work was impossible till England had become once more a free nation, speaking its own tongue, and proud of its own personality. The end of the fourteenth and the opening of the fifteenth century show us an England where these conditions, despite the growing power of the Papacy, were fulfilled. The power of the Pope in England was, despite its total illegality, immense. It was tolerated as a balancing force to political Lollardy, on the one hand, and a turbulent baronage on the other. The country paid a heavy price, in illegal taxation and the farming of benefices in the interests of Rome, for the political benefits derived from the tacit suspension of the anti-papal legislation on the statute-book. But the great power of the papacy during the fifteenth century was exercised in regard to education on the whole, to good effect. During that century the whole social order was changing. The feudal system was in its last stage, and under the stress of the Wars of the Roses the entire machinery of tenures was falling to pieces. The church during this period not only kept learning alive, but developed the grammar schools and made them effective feeders for the universities, drawing upon every class of society for the supply of scholars. It is true that the temporary suppression of the Lollard movement involved the closing of many schools, but it is evident that at the very period when these schools were attacked a larger policy was in the air. I have referred to the statute of 1406 which gave the right of education to all. The famous Gloucester Grammar School Case decided further (in 1410) that at common law every man who was able had the right to teach, and this fact undoubtedly bore fruit. Throughout the century competition among schoolmasters was keen in all the great centers of population, and there can be no manner of doubt that during the fifteenth century, before the introduction of printing, educational activity was preparing the way among all classes for the introduction of the 'New Learning' and the final rejection of papal interference in spiritual affairs.

When we regard the great movement known as the Reformation apart from the local incidents that appear to have precipitated it, we seem to see, in the present connection at any rate, the working of long ripening issues. The crown in the fifteenth century had been glad enough to play off Rome against a rebellious and heretical commonalty and a dangerous baronage. The opening of the sixteenth century presented a new scene of action, from which the feudal barons had disappeared. The commonalty and the king had now one thing in common: the old-standing hatred of papal interference and foreign taxation; while the moving force of the new learning was urging both king and people, unconsciously enough perhaps, towards the same end. The Renaissance, the lessons of history, and the hope of gain, all combined to make men see in a free and purified church that vision of national liberty and national isolation which had always been the ideal of English statesmen from Alfred onwards. So the Reformation came, affirming, only in more downright fashion, the policy laid down by Edward III. in the famous statute of Provisors of Benefices. The independence of the church of England indeed had been asserted over and over again from British times to Magna Charta, from Magna Charta down to the Reformation-Parliament, which, in the seven years from 1529 to 1536, finally did away with *de facto* papal supremacy. The notable fact of the Reformation legislation for us is that it finally broke the bond that Rome in the teeth of history and the law had bound round England. The separation from Rome played a notable part in the history of English education. The first result was an unhappy one. I have pointed out that in the century immediately preceding the Reformation the educational system in England was in many ways effective. In fact there was a primary class of schools that fed the grammar schools, while the grammar schools fed the universities. There are still extant a considerable number of both primary and secondary schools that were created during that period; but the number is but a small proportion of the noble medieval system. Henry VIII. and the ministers of his son Edward VI. in their haste to abolish all traces of Rome, to divert all papal taxation and to absorb the property of papal foundations, destroyed innumerable educational foundations. The chantry legislation alone would have compassed the practical destruction of the medieval system. It is, however, probable, nay, almost certain, that the Tudors had no desire in any way to injure national education. The advancement of learning was a thing dear to the hearts of Henry VIII., Edward VI., Mary I. and Elizabeth, but learning itself fell before the progress of a definite and destructive political policy. It was intended to recreate the destroyed foundations, but the funds nominally allocated for this purpose were diverted to other and less laudable uses.

The course of destruction, however, left the universities untouched—

indeed, their position was strengthened—and the desire for a national system of education grew with the development of the Reformation. Queen Elizabeth showed herself keenly interested in the task of creating the means that should bring the opportunities of learning within the grasp of her poorest subject. It is true that she insisted on the religious conformity of schoolmasters to the established church. To so insist was part of her conception of national unity; but this, at that date, was in no way inconsistent with an enlightened educational policy. Shortly after her accession she published special injunctions on the subject of education, while the bishops closely enquired into the character and quality of the teaching in their dioceses. Parliament moreover specially excepted all educational foundations from annexation on religious grounds, and also by the statute of apprentices of 1562 exempted 'a student or scolar in any of the Universitees, or in any Scoole' from the strict provisions of that act. Moreover, commissioners for charitable uses were appointed—a commission that still occasionally sat in the nineteenth century—who enquired into the abuses of educational foundations. A statute of 1588, which is still in force, attacked with increased vigor the dire corruption of these foundations. The act aimed alike at the universities and the schools. All educational foundations were, moreover, relieved from the burden of subsidies and other taxation. Nor was this all. The queen in 1571 incorporated by statute the Universities of Oxford and Cambridge in order to secure 'the mayntenannce of good and Godly literature, and the vertuouse Education of Youth within either of the same Universities.' It is interesting to note that this quotation from the preamble to the act uses, so far as can be ascertained, the word 'education' for the first time in its modern sense. We may say then that the great queen removed, in so far as in her lay, all artificial drawbacks to education; she opened up all educational endowments to the fittest scholars, and she gave a new and as yet unexhausted impetus to the university system, while she inspired both church and state with a new interest in educational matters.

After the death of Elizabeth, we find that the subject of education was doomed, in view of new political problems and in spite of the personal interest that James I. and probably Charles I. took in letters, to some neglect. Yet Parliament even in the stern days of 'the Great Rebellion' had time to think of education, for we find that Cromwell passed in 1649 a measure for education in Wales as well as a general act that diverted to national education tithe-rent charges of the value of £20,000 a year, and directed that if the annual sum fell below that amount it should be supplemented out of the national exchequer. We thus find in England as early as 1649 provision for parliamentary grants in aid

of national education. Local rates in aid of education existed in rare and sporadic cases, perhaps a century earlier than this; while it is interesting to note that in the colony of Massachusetts Bay as early as October 25, 1644, the general court granted a voluntary rate for the maintenance of poor scholars at Harvard College, and the Connecticut code of 1650 dealt with the whole question of rate-aided education. It is also well to remember that while this beginning of state and rate aid had almost died away in England before the beginning of the eighteenth century, yet the English crown in 1695 confirmed a New England statute creating a system of rate-aided education. The idea, however, soon vanished as completely in the American colonies as it did in the mother country. The restoration of Charles II. in 1660 sounded indeed the death note of the commonwealth conception of national education. It achieved as well an even more lamentable result, for it reduced the great Elizabethan system to a state of coma. Elizabeth, we have seen, insisted on religious conformity, but she did not allow this to interfere with her educational policy. The Act of Uniformity of 1662 and the Five Mile Act of 1665 seem to us to have been literally designed for the extinction of education. These acts involved such a peering into the lives of schoolmasters, such a course of inquisitorial folly, that the position became intolerable. Men would not become schoolmasters, and practically all secondary and (apart from a certain new movement to be referred to immediately) primary education ceased to exist. Education has no meaning when none but political and religious hypocrites are allowed to teach. The campaign against dissent and Roman catholicism may possibly be defended on political grounds, but, from the point of view of national education, the result was lamentable. For the third time national education had been destroyed; it seemed hopeless to try and evolve a fourth system.

That fourth system, incorporating much of the wrecked materials of the old systems, is receiving its coping-stone to-day. We must, therefore, briefly trace its growth. The Uniformity legislation that followed the Restoration was so severe in character that a reaction or a revolt from its operation was inevitable. The decisions of the courts of justice were the first sign of this reaction. The courts held that a schoolmaster, if he was a nominee of the *founder* or of the lay-patron of a school, could not be ejected from the school for teaching without the bishop's license (*Bates's case,* 1670); while it was decided in *Cox's case* in 1700 that there was not and never had been ecclesiastical control over any schools save grammar schools; that the church, in fact, had no control over elementary education. In *Douse's case,* decided in 1701, it was held that it was not a civil offence to keep an elementary school without the bishop's license. Hence the elementary school could escape the inquisition of the bishop whether imposed by statute or

ecclesiastical law. An act of 1714 exempted elementary schools from the penalties of the conformity legislation, and so such schools could, if they would, multiply. The opportunity for a great movement was at hand: the question for England, perhaps the question for civilization, was, would it be seized? To attempt to deal in any detail with the manner in which this opportunity, emerging so obscurely among the bitter political conflicts of the time, was seized, is beyond the scope of a review article,* but I may indicate some broad aspects of the movement.

First, we must remember that the modern system, though it includes now all the endowed educational foundations that had fallen on to evil days at the end of the seventeenth century, did not in any sense spring from those old foundations. It was not till the middle of the nineteenth century that the abuses in these foundations were remedied. "Whoever will examine," said Lord Kenyon in 1795, "the state of the grammar schools in different parts of this kingdom will see to what a lamentable condition most of them are reduced. * * * empty walls without scholars, and everything neglected but the receipt of the salaries and emoluments." The state of the Court of Chancery was such that it would have ruined any individual as well as the endowment to have brought almost any specific case before the courts. These foundations lay dormant till better days—till the days of the grammar school act of 1840 and the endowed schools act of 1869. It may be stated generally that it was not until after 1870 that the ancient grammar schools and endowed schools—the numerous secondary schools of the country which are now proving of such vast importance in coordination with the state-aided primary system—became in any sense efficient. Yet we have to look to a certain class of endowed schools for one source of the modern elementary system. In England and Wales there were in 1842 some 3,000 endowed schools and of these more than 1,000 were founded between the years 1660 and 1730. This extraordinary movement, which has left so vast a result, is certainly difficult to understand. About the year 1660 church and state had practically suppressed endowed education, and yet in the face of that suppression a huge endowment movement arose. One explanation is certainly *Bates's case*, which decided in 1670 that a schoolmaster presented by the founder of a school or by a lay patron could not be ejected from his office by reason of his not holding the bishop's license. This case was a direct incentive to all dissenters, and to all who hated the Erastianity of the period, to found schools where children could be safely educated. This appears to be a reasonable explanation of a movement which was as remarkable as it has been unnoticed by historians. This explanation finds support in the

* I have dealt with it at some length in my volume on 'State Intervention in English Education,' published last year by the Cambridge University Press.

fact that the charity schools movement—largely supported by dissenters—to some extent synchronized in its early rapid development with this school endowment movement. The Act of Uniformity (1662) pressed with great severity on the dissenting schoolmasters, and, in order to give them relief, Dean (afterwards Archbishop) Tillotson and Richard Baxter (the distinguished writer and dissenter) combined in 1674 to draft a 'Healing Act' that should make the spread of elementary education possible. The bishops would not accept the compromise, but it is probable that it had some indirect effect, for the church made few attempts to interfere with dissenting schools, though they were often attended by church children.

The earliest 'voluntary' schools were started in Wales in 1672 by Thomas Gouge, a clergyman of the established church, who had been ejected from his living on Bartholomew's Day, 1662, under the provisions of the act of Uniformity. The bishops sanctioned his Welsh schools, and in 1674 a strong committee of churchmen and dissenters was formed in London to carry on the good work. In 1675 there were 1,850 children at school, of whom 538 were educated by Welsh voluntary subscriptions. John Strype, writing before 1720, connects this work with the charity school system, started in 1698 by the Society for Promoting Christian Knowledge. This latter movement was immensely successful and spread all over the country. In 1729 there were no less than 1,658 schools, containing 34,000 children. I have elsewhere estimated that, allowing a considerable margin for overlapping between the endowment movement and the charity school movement, there were over 2,500 schools of all classes founded in England and Wales between 1660 and 1730, that over one hundred schools received supplementary endowments and that 650 unattached educational charities were created. These schools supplied the poor with such education as was to be had in the eighteenth century—the education given was ineffective enough, but it was at any rate better than nothing. Special efforts were made in heathen Wales. Griffith Jones, a clergyman of the established church, in 1730 started 'circulating schools' in the towns, villages and wild country districts. The teachers stopped in each district for a few months only and then passed on to other centers. The Society for Promoting Christian Knowledge helped the movement, and large funds were supplied by a Mrs. Bevan, who carried on the schools after Griffith's death in 1761. At that date there had been 3,000 schools opened, in which 150,000 scholars had been taught. There were 10,000 children in the schools in 1760. In 1779 Mrs. Bevan died and bequeathed her large property to the carrying on of the work. Her estate was thrown into chancery and the schools were closed for thirty years. Such were the changes and chances of education in the eighteenth century. All higher education—apart from the work, often great, of individuals here and there, such as Isaac

Newton and certain university developments (such as the foundation of various chairs) destined to bear fruit in later days—was asleep, while primary education was poor indeed. It was, however, living and awake and so led on to the great revival of the nineteenth century.

Three new causes united with the new foundations and the charity schools to produce this revival. The first was the Sunday School system, tried by John Wesley in Savannah in 1737, but only introduced into England in 1763, made a national system by Robert Raikes, of Gloucester, in 1780 and brought to London about 1785, when the Sunday School Society was founded. In 1834 there were about 1,500,000 children with 160,000 voluntary teachers in the Sunday Schools of England and Wales. The secular work done by these schools was most valuable. In Manchester we find that in 1834 Sunday Schools were open for secular instruction for five and a half hours on Sunday and for two evenings in the week, and that the ages of the scholars varied from five to twenty-five years. Manchester in those days was still writhing under the scourge of universal child labor, and the Sunday Schools did work that secured the social salvation of thousands. In Mr. Benjamin Braidley's Manchester Sunday School there were 2,700 scholars, taught by 120 unsalaried teachers, all, save two or three, former scholars. The self-sacrifice to be found in the Manchester of those days perhaps more than balanced the sorrows involved in the policy of the Manchester school and David Ricardo. The second cause to which I have referred was the introduction of the monitorial system between 1798 and 1803, by Andrew Bell, a clergyman of the established church (who subsequently founded in 1811 the National School Society), and Joseph Lancaster, who received the close support of King George III., and from whose work sprang in 1814 the British and Foreign School Society. These two men worked with immense vigor at their task and quarreled with no less energy. Their quarrel for precedence as the discoverer of the monitorial system was taken up by the political parties of the day. The tories or church party supported the claims of Dr. Bell, while the whigs and dissenters rallied round Mr. Lancaster. The system was in itself a bad one. It was the parent of the modern pupil-teacher system and gave permanence to the lamentable practice of employing untrained teachers. We may, therefore, believe that the quarrel for precedence was unimportant. It had, however, two vast issues. It created the modern religious or denominational controversy which has had such a marked influence on the development of primary education in England, and it also brought education into modern politics.

The third cause to which I have referred above is this connection between education and politics, a relationship which has evolved the elaborate educational system that found its completion in the education act of 1902. The earliest legislation on the subject of national

elementary education in the modern sense was carried through Parliament in 1802—just a century before the great statute of last year. The factory act of 1802 was intended to deal with the health and morals of children employed in cotton and other mills and factories. The state of the children in these factories and mills was deplorable: ignorant beyond all imagination; housed under conditions subversive of all health, of all morality; working by methods that involved the stagnation of intelligence; these children presented a fearful problem and constituted a positive menace to the future of society. The act of 1802 was passed without discussion: it directed the mill rooms to be whitewashed twice a year and to be ventilated; it ordered an apprentice to have one suit of clothes a year and not to work more than twelve hours a day exclusive of meal times; it forbade work between nine at night and six in the morning; it provided that male and female apprentices should sleep in separate rooms and not more than two apprentices should sleep in one bed; it made medical attendance compulsory in case of infectious disease; it directed the mills to be inspected by visitors appointed by the justices and ordered the children to be taught the elements of knowledge and the principles of christianity. It is an awful picture; a picture for which the discovery of machinery and of the usefulness of children in machine work are responsible. This reformatory measure was petitioned against in the following year by both manufacturers and parents and it was never enforced. Many generations of little, seven-year-old slaves—the thought is heart-breaking—were to be worn away in the mills before, late in the century, effective relief came. Until 1878 children under nine years of age could be employed in silk mills. At the present time every child in the country—who is not specially exempt on the ground of adequate private teaching, sickness, inaccessibility of school, or other reasonable excuse—is compelled to attend school full time between the ages of five and at least twelve years (save in the case of children employed in agriculture when the child may be partially exempted at eleven). Moreover every local education authority may make by-laws compelling attendance up to the age of fourteen years. The child can, however, be employed during holidays or during hours when the school is not open; and this is a source of abuse. A child can not do his school work and school play and also be an up-hill down-dale errand boy. However, the change in the matter of child labor is remarkable since that year of grace 1802 and it may be admitted that some forms of employment in non-school hours are better than idleness with its concomitant evils.

From this time parliamentary interest in educational matters increased very rapidly. Mr. Whitbread's bill of 1807 provided for the establishment of schools and the appointment of schoolmasters by

the magistrates in every school-less district. All poor children were to be entitled to two years schooling between the ages of seven and fourteen years. The bill was mangled in the Commons and lost in the Lords. In 1816 a select committee was appointed to report on the education of the lower orders. In 1818 it reported on the condition of the country at large. 'The anxiety of the poor for education' was daily increasing, though the opportunities were very bad. The single-school (mostly church-school) districts showed, however, an increasing degree of liberality, and the religious views of the school were not pressed upon the children of parents holding other views, provided that the children were really taught such other views. This committee recommended the universal use of a conscience clause, the establishment of rate-supported, free parochial schools in very poor districts—the principle of the act of 1870—and, in rich districts, the making of grants to aid in the building of schools the maintenance of which would fall upon voluntary subscribers—the principle adopted by Parliament in 1833. Had both these suggestions been accepted in 1818, educational progress in the nineteenth century would have been far more rapid.

In 1820 Mr. Brougham introduced his first education bill. In his speech he fully recognized the labors of the clergy on behalf of education, and he noted the great improvement of the position since 1803. Then only one in every 21 persons in the population was at school, while in 1820 it was one in every 16 persons. This meant, however, that still one fifth of the population was without the means of education. Moreover, London was still 'the worst-educated part of Christendom.' The bill proposed the universal establishment of parochial schools with efficient teachers. Funds were to be found by local rates and by the diversion of old endowments. The religious teaching was to be undenominational. This bill was opposed both by the dissenters and the Roman Catholics, and was abandoned after the second reading.

Thirteen years now passed without legislative effort, but these years saw the growth of a great volume of public opinion. Mr. Brougham's pamphlet entitled 'Observations on the Education of the People,' published in 1825, ran through twenty editions in less than a year, and on all sides the importance of the problem received recognition. The year 1833 produced the first results of the educational renaissance. On Saturday, August 17, the House of Commons voted the sum of £20,000 in aid of private subscriptions for the erection of school-houses. The new era of definite state intervention in the education of the people may be said to have opened with this vote. From that date to this an ever-increasing annual vote for education has dignified and justified the statute book.*

* Over £10,000,000 was voted by Parliament for Elementary Education in England and Wales for the year 1902–3.

(To be continued.)

DISCUSSION AND CORRESPONDENCE.

THE QUESTION OF RACIAL DECLINE.

To the Editor: I have read in your June issue the article entitled 'Race Decline' by George J. Engelmann, M.D., of Boston. The writer states 'The American population is not holding its own, it is not reproducing itself,' etc., and quotes statistics of college classes and of Massachusetts to prove it. When a young man thirty years ago I heard the same story, and people predicted that the American people of native stock would be extinct in a few generations. The census of 1900 flatly contradicts the gentleman's statements. It shows that the rate of natural increase is not exceeded by any nation on the face of the globe. What has doubled the population (white) of the states in the south since 1870? There is but little immigration to that section. Also what causes the great increase of population in states like Indiana where the foreign born are decreasing?

The fact is that the native population is increasing very rapidly and is not dying out, not even in Massachusetts. We hear a great deal about the prolific French Canadians and their great natural increase. It may astonish some people that the native Americans are increasing just as rapidly and in the south much more so. I will quote a few statistics taken from the recent census.*

Native born white native parentage	41,053,917
Under 20 years of age	19,556,558
Percentage under 20	47.6%

* Vol. 2—Population, part 2, page 2, Table 1.

In the province of Quebec (French Canada) the 1901 census shows that 49 per cent. of the population were under twenty years of age, or a little more than 1 per cent. more than the native Americans. If we omit those under five years of age the percentages will be as follows:

Native American from 5 to 19 inclusive	34.3%
French Canadians from 5 to 19 inclusive	34.6%

This indicates a greater death rate among the French Canadians under five years of age. Now for figures for typical native states I take Indiana in the north, and North Carolina in the south. In the former the foreign-born are but 5½ per cent. of the population and in the latter less than half of 1 per cent.

Indiana.	
Under 20 years of age	46.3%
From 5 to 19 inclusive	34 %
North Carolina.	
Under 20 years of age	51.7%
From 5 to 19 inclusive	37 %

Notice how much larger the percentage of children in North Carolina is than in French Canada. This is typical of all the southern states. Among the mountaineers the percentage of children even exceeds this, and a comparison of the number of children among these people and the French Canadians would make the latter look like a decadent race. It is true that in Massachusetts and some of the adjoining states the foreign element increases in the natural way more rapidly than the native, but this does not hold good as to the whole country.

But the showing made by Massachusetts is not as bad as indicated by Dr. Engelmann. I quote from Vol. 3 of

the U. S. Census Vital Statistics, Part 1, page 356, for the census year ending May 31, 1900. This does not indicate that the native is dying out in Massachusetts.

Massachusetts: Births and Deaths.

Both parents native, births....		21,343
Both parents native, deaths (all ages)		15,357
Natural increase		5,986
One or both parents foreign	44,252	
Foreign born..........	624	44,876
Natives, one or both parents foreign, deaths (all ages)	16,194	
Foreign born	13,645	29,839
Natural increase.......		15,037

While the above shows a very healthy increase among the natives of Massachusetts it also indicates a larger increase among the foreign element. But in this connection it must not be forgotten that a very large proportion of those included in the foreign element are of the same stock as the natives. Thus in Massachusetts there are nearly a half million English, Scotch, Welsh and English Canadians, both foreign and native born. I think the foregoing shows pretty conclusively that the natives are not dying out and that all opinions to the contrary are based on a false foundation.

C. E. Smith.

Brooklyn, N. Y.

[We publish Mr. Smith's letter as the question is of such importance that it should be discussed from all sides. It ought to be said, however, that statisticians hesitate to draw conclusions as to racial increase from the figures of the census. When the native population increases from one census to another, this is partly and may be entirely due to the children of foreign parents who are counted as natives. When Mr. Smith gives figures showing that in Massachusetts the births when both parents are natives exceed the deaths when both parents are natives, it should be noted that the births come from a considerably larger group than the deaths. The native children of foreign parents are not counted among the deaths, but their children are counted among the births. It is also true that after a period when the native population has increased (perhaps only by children of foreign parents) there would be an excess of births. Mr. Kuczynski in his careful analysis of the fecundity of the native and foreign-born population in Massachusetts (*Quarterly Journal of Economics*, November, 1901, and February, 1902) states that in Berlin, where proper statistics are collected such as do not exist in this country, the birth rate is not sufficient to maintain the population. But in Berlin there was an annual birth rate of 10 for every 100 married women in child-bearing age, whereas it was only 6.3 in the native population of Massachusetts.

It seems also fair to our readers to state that we do not accept the conclusions of Dr. Engelmann published in the last number of the Monthly. In an article such as Professor Fleming's on 'Wireless Telegraphy,' we have simply to learn what the leading authority on the subject teaches us. When we leave the exact sciences, and especially when we enter the field of applied sociology, we have our science to make. The fact that sociology is now in about the condition of the physics of three hundred years ago does not detract from its interest, but rather adds to the possibilities of progress. Readers should, however, remember that while a physicist can usually speak for the science of physics, a sociologist can usually only speak for himself. The fact that the editor of this journal does not agree with Dr. Engelmann in regard to the interpretation of statistics does not necessarily mean that Dr. Engelmann is mistaken, but only that the subjects are not yet in the field of exact science.

Dr. Engelmann claims that an older age at marriage does not mean a smaller family, that the marriage rate of the college graduate is higher and the size of the surviving family larger than in the population at large, and that the decreasing size of family is entirely voluntary. We think that he has established none of these conclusions. Adequate statistics may not be at hand correlating the size of family with the age of marriage, but it seems almost certain that there is an inverse correlation, those who marry later having fewer children. This would hold especially for women—and older men are likely to marry older women—and for men who remarry. It is also of course true that earlier marriages produce a more rapid sequence of generations and a larger population.

Dr. Engelmann gives 2.1 as the size of family of graduates more than twenty years out of college and 1.9 as the size of family of the native-born in Massachusetts, and tells us that the college graduate does more towards reproducing the population than does the native American of other class. He appears to be in serious error in his statistics. A certain loyal Princeton graduate discovered that his class of '76 had 2.7 surviving children for each married graduate. Whether this case is typical or not we do not know, but Dr. Engelmann gives it the same weight in his average as the 1.86 obtained from 1,401 Harvard graduates. The families of Princeton and Yale graduates and of many Harvard graduates coming from a region having higher fertility can not be compared with the decadent native population of Massachusetts, nor can college graduates in part of foreign origin be compared with the exclusively native population. Dr. Engelmann compares the native surviving Massachusetts family of 1.9 with that of college graduates of more than twenty years' standing. The native population includes girls of fourteen and women just married. The average number of living children of native women of Massachusetts between the ages of forty and forty-nine was 2.13. With this family and a marriage rate of 79 per cent. the population is rapidly decreasing. Harvard graduates, with a marriage rate of 71.4 and a family of 1.86 surviving for a time are destined to even more rapid extermination. The Harvard graduate of New England stock is doubtless still more infertile, but we have no exact information in regard to this, nor as to whether or not the college graduate is more infertile than the race and class from which he comes. EDITOR.]

SCIENTIFIC LITERATURE.

PSYCHOLOGY.

THERE has just been published a group of psychological books which could scarcely have been produced elsewhere. In both volume and value of work, American psychologists appear to hold their own with Germany and to surpass Great Britain or France. The books to which we especially refer are 'Experimental Psychology and Culture,' by Professor Stratton, of the University of California; 'Outline of Psychology,' by Professor Royce, of Harvard University; 'Genetic Psychology for Teachers,' by Dr. Judd, of Yale University, and 'Why the Mind Has a Body,' by Professor Strong, of Columbia University.* If we go back a couple of years, there may be added 'Talks to Teachers,' by Professor James, of Harvard University; 'Psychology and Life,' by Professor Münsterberg, of Harvard University; 'Fact and Fable in Psychology,' by Professor Jastrow, of the University of Wisconsin; 'Introduction to Psychology,' by Professor Calkins, of Wellesley College; 'Experimental Psychology,' by Professor Titchener, of Cornell University, and 'Analytical Psychology,' by Professor Witmer, of the University of Pennsylvania. We have in addition the monumental 'Dictionary of Psychology,' edited by Professor Baldwin, of Princeton University, the third and last volume of which has just been published, and various works limited to a special field, such as Professor James's 'Varieties of Religious Experience' and 'Aristotle's Psychology,' by Professor Hammond, of Cornell University. The books can not be said to represent a school of psychology, but they show certain rather definite tendencies. They are scientific, being based on the results of recent experimental research, and yet they tend to maintain an intimate connection with philosophy. The relations to education are strongly emphasized. The human interest and literary style are noticeable, being scarcely equaled by similar works in other sciences.

This is not the place for critical reviews, but a few words may be said about the contents of the books that have just been issued. Professor Strong's work is somewhat technical in character, but is scarcely beyond the comprehension of the untrained reader. It discusses the relations of mind and body, defending a parallelism that gives room for the efficiency of mind and an idealism that makes consciousness the reality that appears as the brain-process. The books by Professor Royce and Dr. Judd both appear in series for teachers, but they differ widely in their contents and methods. The former is a general treatise on psychology, in which the phenomena are classed in a new way under the heads of sensitiveness, docility and initiative; the latter contains chiefly concrete facts of direct use to teachers. Professor Stratton's book is a well-informed and well-written account of some of the results of experimental psychology treated in relation to wider interests. The difficulty in recommending a book on psychology for students of other sciences or for general readers is not now in the lack of books, but in their number and excellence.

* The books are published by The Macmillan Company, except Professor Judd's which is one of the International Education Series of the Appletons.

THE PROGRESS OF SCIENCE.

LORD KELVIN ON 'CREATIVE PURPOSE.'

THERE has been in progress in the columns of the London *Times* a correspondence on certain serious topics that has aspects both amusing and pathetic. Lord Kelvin, in moving a vote of thanks at the close of a lecture before the Christian Association of University College, London, said that "science positively confirmed creative power. . . . Modern biologists were coming to a firm acceptance of something, and that was a vital principle. . . . They were absolutely forced by science to admit and to believe with absolute confidence in a directive power." Lord Kelvin subsequently explained that a fortuitous concourse of atoms would account for the formation of a crystal, but that creative power is necessary for the growth of a sprig of moss. Sir William Thistleton-Dyer, director of the Kew Botanical Gardens, calls Lord Kelvin sharply to account, saying that 'for dogmatic utterance on biological questions there is no reason to suppose that he is better equipped than any person of average intelligence.' Sir William is, however, ready to enter the field of physics, and tells Lord Kelvin that his ether is 'a mere mathematical figment.' Sir John Burdon-Sanderson intervenes to express regret that "A most distinguished British botanist has thought it necessary to 'cross swords' with the most distinguished of British physicists with reference to a question on which it is desirable that all men of science should be in accord," and to disclaim on the part of his own science, physiology, the opinion that Lord Kelvin is not competent, when von Helmholtz has spoken of his 'surprising acuteness, clearness and versatility.' But Sir John immediately proceeds to state that physiologists do not believe in a vital principle, that the processes of animal and plant life are governed by the natural laws which have been established for the inorganic world. Mental processes and organic evolution can not, however, be directly measured or observed. In spite of the desirability of accord and of Lord Kelvin's great competence, he is mistaken as regards Sir John's science, though psychology and organic evolution may very well be outside the range of exact science. Sir Oliver Lodge, the eminent physicist, does not like the phrase 'creative power,' but believes that the formation of an animal or plant requires in addition to the laws of mechanics 'the presence of a guiding principle or life-germ.' He also regards 'telepathy' as a recently discovered fact. Professor Ray Lankaster, director of the British Museum of Natural History, thinks that an injustice would be done both to Lord Kelvin and to his critics unless he points out the significant features of the matter. Professor Karl Pearson, Mr. W. H. Mallock and others have joined in the discussion, and it is the theme of editorial articles in the *Times* and *The Spectator*, both of which are orthodox and dogmatic.

It is a fact of some interest that British physicists have been inclined to religious orthodoxy — Faraday, Maxwell, Stokes and Kelvin may be mentioned. Sir Oliver Lodge believes in telepathy and Sir William Crookes in ghosts. The physical sciences have outlived their conflict with current theology, whereas in the past half century biology has had to bear the

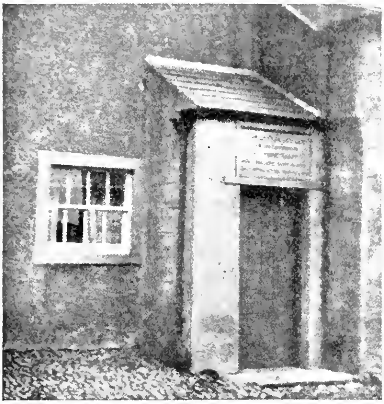
brunt. The physicists hold that their realm is governed by their laws, but that the biological kingdom is a theocracy. It appears that there is as much or as little evidence for teleology in an earth suited for life as in its inhabitants, as much or as little evidence for creative purpose in a crystal or a solar system as in a sprig of moss or a man. But perhaps such a statement is in continuation of the dogmatism, to which attention has been called.

CELEBRATIONS IN HONOR OF DALTON AND LIEBIG.

THERE have recently been celebrated the centenary of Dalton's discovery of the atomic theory and the hundredth anniversary of Liebig's birth. The ceremonies in honor of Dalton were at Manchester, a city which gave birth to two of the great scientific advances of the last century, the atomic theory and Joule's work on the mechanical equivalent of heat. Manchester has an ancient and active Literary and Philosophical Society, which invited Professor F. W. Clarke of the U. S. Geological Survey, chairman of the International Commission on Atomic Weights, to give its Wilde lecture. He reviewed the history of the atomic theory from its first conception among the Greeks to the present day and outlined the work still needed. Professor J. H. van't Hoff, of Berlin, was presented with an address by the Owens College Chemical Society, and laid the cornerstone of the extension of the chemical laboratory. The Wilde medal of the Literary and Philosophical So-

ciety was presented to Professor Clarke, and he and Professor van't Hoff received the degree of Doctor of Science from Victoria University.

John Dalton was born in 1766 of Quaker parentage. He began to teach school at the age of twelve, and supported himself through life by teaching, and later by making analyses for local manufacturers, being thus one of the earliest professional chemists. From 1793 until his death in 1844 he lived quietly at Manchester, unmarried and entering but little into society. He was made secretary of the Literary and



MEMORIAL TABLET OVER DOOR OF HOUSE IN WHICH JOHN DALTON WAS BORN.

From a photograph supplied to *Nature* by Mr. A. Humphreys. The inscription on the tablet reads:—"John Dalton, D.C.L., LL.D., the Discoverer of the Atomic Theory, was born here Sept. 6, 1766. Died at Manchester July 27, 1844."

Philosophical Society in 1800, was its president after 1817, and carried on his chemical work in the rooms of the society. He was a member of the Paris Academy before he was elected to the Royal Society, but finally received all the usual honors. Dalton once said:

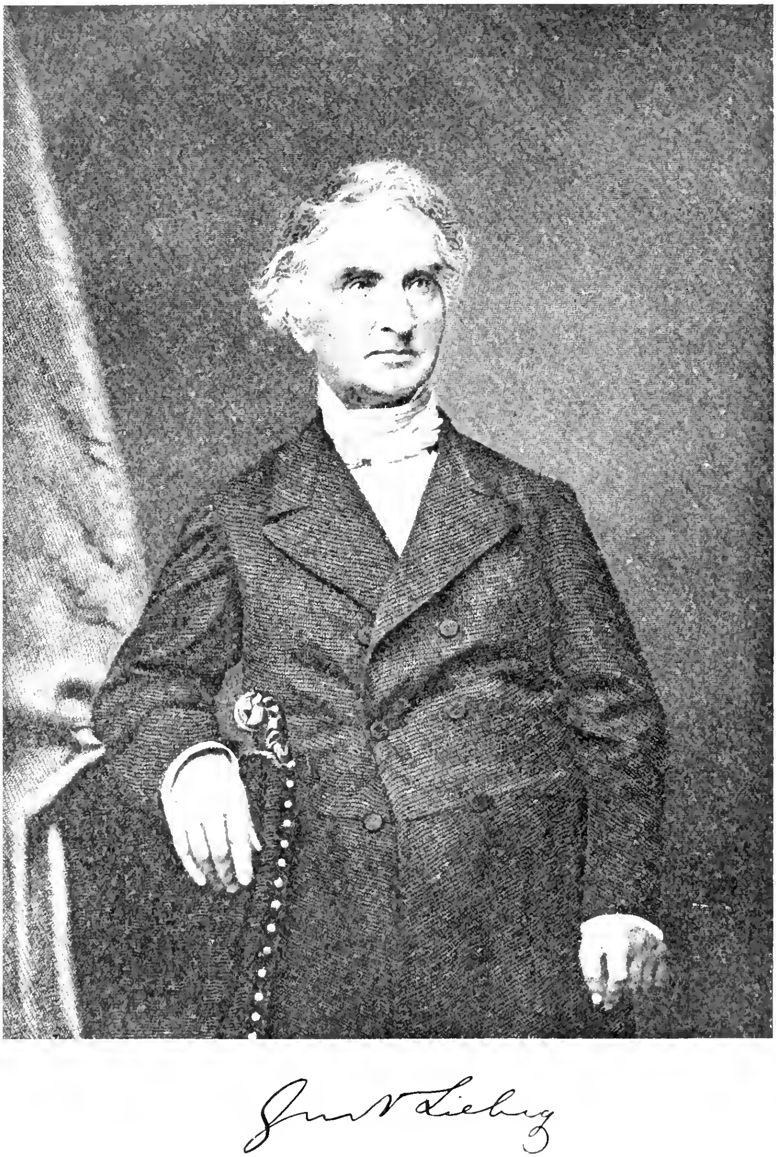
> With regard to myself, I shall only say, seeing so many gentlemen present who are pursuing their studies, that if I have succeeded better than many who surround me in the different walks of life, it has been chiefly—nay I may say almost solely—from unwearied assiduity. It is not so much from any superior genius that one man possesses over another, but more from attention to study and perseverance in the objects before them, that some men rise to greater eminence than others. This it is, in my opinion, that makes one man succeed better than another.

Yet his own life supports the theory of innate genius, for though he worked diligently to the end, his great discoveries were made while he was a young man. It is generally known that he discovered color-blindness, sometimes called Daltonism; he also did much work in meteorology, recording over 200,000 observations; he is said to have enunciated the law of the expansion of gases before Gay-Lussac; he carried on research in different departments of physics and chemistry. But of course his great discovery was the atomic theory, the centenary of which has just been celebrated. The theory, like most others, was of gradual development, but, as Dalton says in a letter to his brother in 1803, he had 'got into a track that has not been much trod before,' and this track has become the highway of modern chemistry.

Justus von Liebig was born on May 12 of the year in which Dalton formulated the atomic theory, and the hundredth anniversary of his death has been celebrated in Germany and here. In New York there was a meeting of chemists, which was addressed by President Remsen, of the Johns Hopkins University, whose laboratory has done much to carry forward the work in organic chemistry which Liebig founded; by Professor Brewer, of Yale University, one of Liebig's oldest pupils, who has continued his work on agricultural chemistry, and by Dr. Carl Duisberg, managing director of the Farbenfabriken of Elberfeld, who spoke of Liebig's influence on the chemical industries.

There will be found articles on Liebig in the third, ninth and twentieth volumes of this journal, the last being

an extremely interesting autobiography. Like many others who have attained eminence in science, Liebig shelves of the Court Library and made his own experiments. At the university things were not much more to his



did not profit much from the existing system of education; but as a boy he read all the books on chemistry in the order in which they stood on the taste. He attended the lectures of Kastner, regarded as an eminent chemist, but capable of telling his students that 'the influence of the moon upon

the rain is clear for as soon as the moon is visible a thunderstorm ceases.' The science of the universities was under the domination of the 'speculative physics' of Hegel and Schelling, whose chemistry is fairly represented by such a quotation as "Water contains just the same as iron, but in absolute indifference as yonder in relative indifference, carbon and nitrogen, and thus all true polarity of the earth is reduced to an original south and north which are fixed in the magnet." What Liebig accomplished will be better appreciated if the deplorable state of science in the German universities is recalled.

Liebig was made professor of chemistry at Giessen at the age of twenty-one, and full professor two years later. He immediately proceeded to establish a laboratory for students, the prototype not only of chemical laboratories, but of the laboratory method in science. In 1852 he removed to Munich, where he died in 1873. Like many other men eminent in research, Liebig was a great teacher, an editor and a popularizer of science. He also combined the discovery of facts with the formulation of wide-reaching theories. Neither the facts nor the theories can be described here; it suffices to say that Liebig may properly be regarded as the founder of organic, physiological and agricultural chemistry.

THE AMERICAN MUSEUM OF NATURAL HISTORY.

THE thirty-fourth annual report (that for 1902) of the American Museum of Natural History in New York City records the events of a prosperous year for the institution. During the year the membership increased materially, and the attendance on lectures was larger than ever before. Several scientific societies held their regular meetings in the building. In October, 1902, the International Congress of Americanists held its thirteenth annual session at the museum, and discussed subjects relating to 'The Native Races of America' and 'The History of the Early Contact between America and the Old World.'

In May 1902, upon the arrival of the news of the disaster in Martinique, Dr. Hovey, of the Geological Department, was detailed by the president to investigate the causes of the eruptions, and his work has placed the museum among the leading contributors to seismology.

The additions to the collections of mammals during the year numbered more than 2,000, secured largely through the museum collectors. The gift of the Peary Arctic Club of about one hundred mammals, collected by Commander Peary on his last Arctic expedition, is especially noteworthy. The museum is now the richest in the world in mammals from Arctic America. The donations from the New York Zoological Society and the Central Park Menagerie are of great value to the museum. The specimens of mammals obtained by the Andrew J. Stone Expedition in North British Columbia form the largest single collection that has ever been brought down from the north. In the Bahamas and Virginia material was collected for special bird groups for the museum. The vertebrate paleontological collections of the museum were enriched by expeditions maintained in the field, and the establishment of a fund by a member of the board of trustees for providing material to illustrate the origin and development of the horse produced immediate results of the highest importance. The Cope collections, the purchase of which was effected in the year, include fossil reptiles, amphibians and fishes, and the Pampean collection of fossil mammals from South America.

A number of archeological collections not before exhibited were installed, notably the valuable collections made in the southwest under grants furnished by the Messrs. Hyde. Through

the generosity of the Duke of Loubat and contributions made by the president of the museum and the Messrs. Hyde, the museum came into the possession of a very large amount of material illustrating the culture of ancient Mexico. Another exhibit worthy of note is that of a portion of the material obtained during the researches in the Delaware which have been carried on for more than twenty years. It seems to show that man was in the valley of the Delaware at the time that certain of the glacial deposits and those immediately following were made. The year was signalized by the conclusion of the explorations of Messrs. Bogoras and Jochelson, on account of the Jesup North Pacific Expedition, and their return to the museum with vast quantities of ethnological material. The expedition has covered the whole district from Columbia River in America westward to the Lena in Siberia, and it is already evident that the relationship between Asia and America is much closer than had hitherto been supposed. The Huntington California Expedition and the North American Research Expedition were continued in 1902, and much information gained in regard to certain of the native races of America. The east Asiatic work of the Expedition to China promises important scientific results. The Hyde Expedition carried on work in the southwest and in northern Mexico. The results of the work of the Mexican Expedition throw much light on the burial customs of the ancient Zapotecans, and the collections obtained add materially to the importance of the collection in the museum. Rare specimens of gold, copper and jadeite secured by the expedition, added to those already in the museum, make this part of the Mexican collection the best in any museum. From the Duke of Loubat the museum received a gem collection of great importance from the state of Oaxaca. Local explorations were carried on in the Shinnecock and Poosepatuck reservations on Long Island and Staten Island and at Shinnecock Hills.

Several additions were made during the year to the gem collection, in the Department of Mineralogy, namely, five magnificent crusts of amethyst, a large yellow sapphire, two parti-colored sapphires, an immense star sapphire, and a curious archaic axe of agate, gifts of Mr. J. Pierpont Morgan. A splendid collection of gold and silver coins from the Philadelphia mint, the gift of Mr. Morgan, was placed in the gem room.

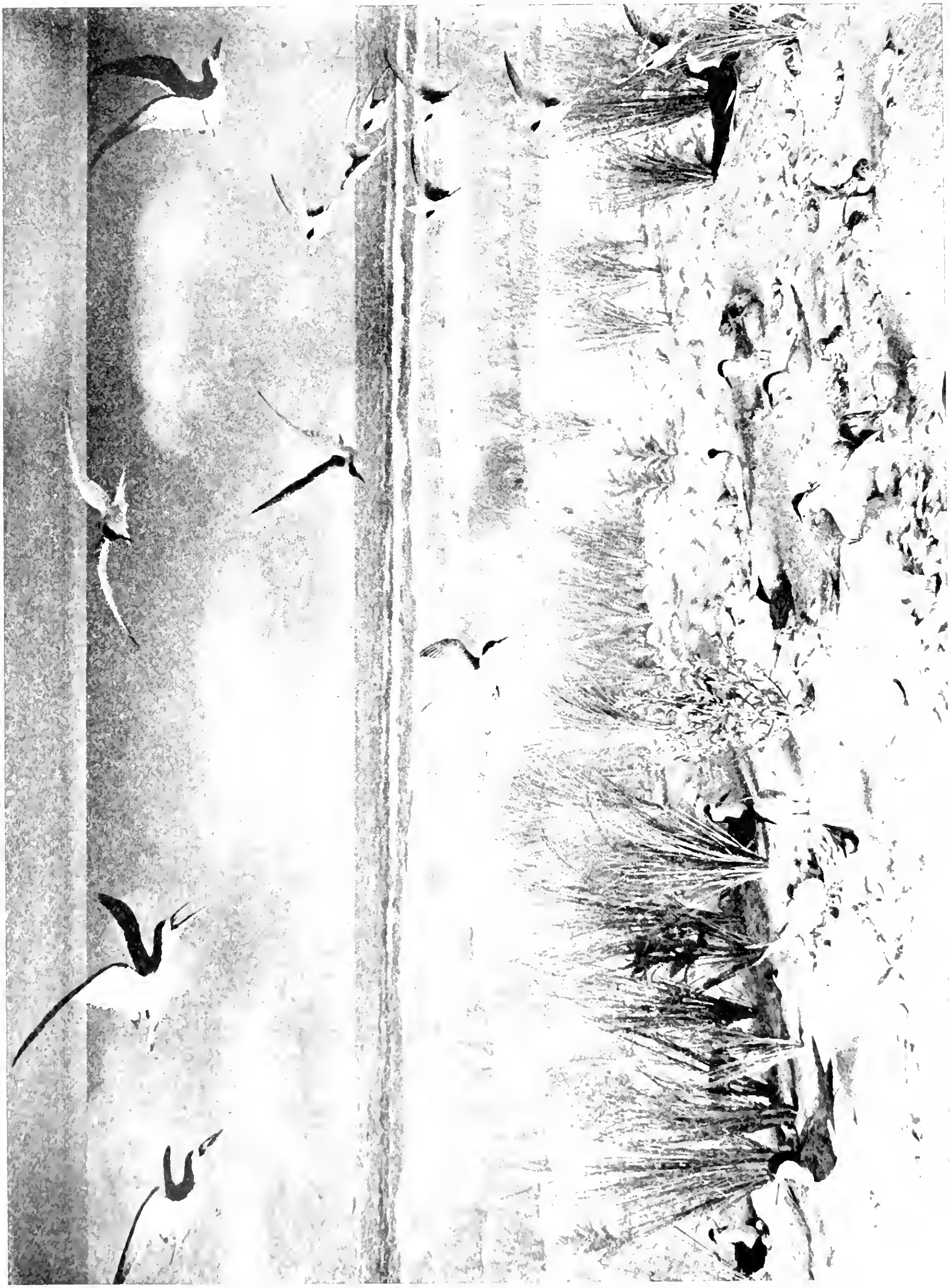
The Department of Invertebrate Zoology received an important accession in a collection of West Indian corals, actinians and alcyonarians collected in Jamaica. The New York Zoological Society and the Department of Parks were the principal donors of reptiles and batrachians.

A section of one of the giant trees of California has been placed on exhibition and attracts considerable attention. The tree from which the section was cut was 1,341 years old; it was almost 30 feet in diameter at the base, and had reached a height of 300 feet. Cards indicating the discoveries in biology during the life of the tree have been attached to the mounted section.

In the Department of Entomology, the Hoffmann collection of butterflies was transferred to the new cases, and the Schauss collection of moths provisionally arranged. From the Black Mountains of North Carolina, 7,000 specimens were obtained for this department. The death of the Very Reverend Eugene A. Hoffmann, D.D., LL.D., removed a warm friend of the museum and a substantial support from the Department of Entomology.

The publications of the scientific results attending the investigations of the museum in various lines progressed during the year. Two numbers of the 'Memoirs' were issued, namely 'Kwa-

SCENES FROM THE PTARMIGAN GROUP



Central Portion of the Group of Beach-Breeding Birds of Cobb's Island

kiutl Texts' by Franz Boas and George Hunt, and 'The Night Chant, a Navaho Ceremony' by Washington Matthews. The amount of 'Bulletin' matter published is the largest in the history of the museum. Nine numbers of the *Museum Journal* and six 'guide leaflet' supplements were issued. The supplements describe collections in the museum, and their popularity is shown by the fact that several thousand were sold in the year at the entrances.

Several courses of lectures were offered under various auspices: To teachers, to members of the museum, and to the public (holiday course), under a grant from the state; to teachers, by the museum, in cooperation with the Audubon and Linnæan Societies; to the public, by the City Department of Education in cooperation with the museum.

In summing up his report, the president mentions several items that indicate the progress of the institution: "In concluding this my twenty-second report, I take pleasure in assuring the members of this board that the past year has been one of achievement. The increase in the annual appropriation, the growing popularity of the lectures, the large sums spent for laboratory research, the long list of publications, the opening of new exhibition halls, the appropriation by the city of $200,000 for a new power house, the receipt of large invoices of ethnological material from Siberia and China, the conclusion of negotiations leading to the purchase of the Cope collection, and the departure of several exploring expeditions, are only a few of the indices of activity at the museum, of the generosity of our friends, and of appreciation on the part of the city officers and the visiting public."

THE AMERICAN PHILOSOPHICAL SOCIETY.

In the complex organization of American scientific societies, the American Philosophical Society 'held at Philadelphia for the promotion of useful knowledge' seems to be maintaining a place of its own. It was originally a national society founded on the model of the Royal Society, and the general meetings held last year and this show that it has to a certain extent maintained this position. Members from Philadelphia and the vicinity acted as hosts, and were able to welcome a considerable number of members from different parts of the country. Both the arrangements for social intercourse and the program compared very favorably with those of the meeting of the National Academy of Sciences, held at Washington in the same month. The meeting lasted for three days. In one of the evening sessions Dr. Edgar F. Smith, professor of chemistry in the University of Pennsylvania and president of the society, made an address on its origin and early history, drawing from original documents much interesting information in regard to the beginnings of science in America. At the same session Dr. D. C. Gilman, president of the Carnegie Institution, spoke of its work during the past year. After these addresses, which were given in the hall of the Historical Society of Pennsylvania, there was a reception, and on the following evening a dinner was given at the Hotel Bellevue, at which Professor W. B. Scott, of Princeton University, was toastmaster.

The meetings were held in the hall of the society, and a considerable number of interesting papers were presented. The American Philosophical Society includes philology and economics in its scope, and papers were presented by Professor March, of Lafayette College, on the development of the English alphabet; by Professor Haupt, of the Johns Hopkins University, on archeology and mineralogy; by Professor Jastrow, of the University of Pennsylvania, on the Hamites and Semites in the tenth chapter of Genesis, and by Professor Schelling, of the University of Pennsylvania, on the

supernatural in Elizabethan and Jacobean plays. We give these titles, as it is not usual to combine in one program papers in the natural and exact sciences and in the philological and historical sciences. The whole question of the relation of these two great groups of sciences to each other requires solution, and it is of interest to note that they were successfully combined at Philadelphia. The following new members were elected:

Residents of the United States—Edward E. Barnard, Sc.D., Williams Bay, Wis.; Carl Hazard Barus, Ph.D., Providence, R. I.; Franz Boas, Ph.D., New York; William W. Campbell, Sc.D,. Mt. Hamilton, Cal.; Eric Doolittle, Philadelphia; Basil Lanneau Gildersleeve, LL.D., Baltimore; Francis Barton Gummere, Ph.D., Haverford, Pa.; Arnold Hague, Washington, D. C.; George William Hill, LL.D., Nyack, N. Y.; William Henry Howell, Ph.D., Baltimore; Edward W. Morley, Ph.D., Cleveland; Harmon N. Morse, Ph.D., Baltimore; Edward Rhodes, Haverford, Pa.; Alfred Stengel, M.D., Philadelphia; William Trelease, Sc.D., St. Louis.

Foreign Residents.—Anton Dohrn, Naples; Edwin Ray Lankester, LL.D., F.R.S., London; Sir Henry E. Roscoe, F.R.S., D.C.L., London; Joseph John Thomson, D.Sc., F.R.S., Cambridge, Eng.; Hugo de Vries, Amsterdam.

Action was also taken looking to the adequate celebration of the two hundredth anniversary of the birth of Franklin, the founder of the organization. This was expressed in the following preamble and resolution which were unanimously adopted:

Inasmuch as the two hundredth anniversary of the birth of Benjamin Franklin occurs in January, 1906, it is proper that the American Philosophical Society, which owes its existence to his initiative and to which he gave many long years of faithful service, should take steps to commemorate the occasion in a manner befitting his eminent services to this society, to science and to the nation. Therefore be it

Resolved, That the president is authorized and directed to appoint a committee of such number as he shall deem proper to prepare a plan for the appropriate celebration of the bi-centennial of the birth of Franklin, and report the same to this society.

SCIENTIFIC ITEMS.

Professor J. Peter Lesley, the eminent geologist, died at Milton, Mass., on June 1, aged eighty-three years.

The freedom of the city of Rome has been conferred on Mr. G. Marconi.—The German Chemical Society has conferred its gold Hofmann medals on Professor Henri Moissan and Sir William Ramsay.

Dr. A. C. Abbott, professor of hygiene at the University of Pennsylvania, has been appointed chief of the Bureau of Health at Philadelphia.—James Harkness, A.M., since 1888 professor of mathematics at Bryn Mawr College, has been appointed by the board of governors Redpath Professor of Mathematics at McGill University.—Dr. W J McGee has been appointed chairman of the committee of the International Geographical Congress of 1904, succeeding General A. W. Greely, who has resigned owing to ill health and the pressure of official duties.—Dr. A. Graham Bell has resigned the presidency of the National Geographic Society.

At the meeting of the board of trustees of the Leland Stanford Junior University held on June 1, Mrs. Leland Stanford resigned and surrendered all the powers and duties vested in her by the terms of the grant founding the university, under which she had complete control. That control is now vested in the board. Mrs. Stanford will be elected a trustee, and will be elected president.

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MONTHLY.

AUGUST, 1903.

MODERN VIEWS ON MATTER.*

By Sir OLIVER LODGE, Hon.D.Sc., F.R.S.

THE nature of matter has been regarded by philosophers from many points of view, but it is not from any philosophic standpoint that I presume in this university to ask you to consider the subject under my guidance. It is because new views as to the structure and properties of what used to be called the ultimate atom are now being born, and because these views, whether they succeed in ultimately establishing themselves in every detail or not, are of surpassing interest, that I have chosen this very recently deciphered chapter of science as the subject-matter for the lecture—the Romanes lecture—to be given this year in remembrance of a man whom I knew as a friend, and whose mind, if he had been alive to-day, would have been widely open to these most modern developments of physical science. Nor would the admittedly speculative character of some of the hypotheses now being thrown out have deterred him from hearing about them with the keenest interest.

If I may venture to say so, it is the more philosophical side of physics which has always seemed to me most suitable for study in this university; and although I disclaim any competence for philosophic treatment in the technical sense, yet I doubt not that the new views, in so far as they turn out to be true views, will have a bearing on the theory of matter in all future writings on philosophy; besides exercising a profound effect on the pure sciences of physics and chemistry, and perhaps having some influence on certain aspects of biology also.

* The Romanes Lecture, delivered in the Sheldonian Theatre, Oxford, June 12, 1903. Copyright by The Science Press.

In admitting that I am going to promulgate a speculative hypothesis, that is a hypothesis for which there is evidence but not yet conclusive evidence, I must not lead you to suppose that the whole of what I have to say is of this character. On the contrary, much of it is certain, that is to say, is accepted by a consensus of opinion to-day among those who by reason of study are competent to judge. I will endeavor carefully to discriminate between what is in this sense certain and what must still be regarded as doubtful and needing further support.

To treat the subject properly, to give all the evidence as well as the results, would need a volume, or a course of lectures; and in order to be brief I must frequently be dogmatic, but I shall only intend to be so in those places where I feel sure that the physicists present (whom here I salute) will agree with me. When I have a dogma of this kind to propound I shall call it a thesis. The more speculative opinions I shall plainly denominate hypotheses.

1. My first thesis is that an electric charge possesses the most fundamental and characteristic property of matter, viz., mass or inertia; so that if any one were to speak of a milligram or an ounce or a ton of electricity, though he would certainly be speaking inconveniently, he might not necessarily be speaking erroneously. At the same time it would be well to mistrust any one who employed such a phrase, except in speaking to experts: he would most likely be talking nonsense; but if he talks nonsense to experts, his blood is on his own head.

In order to have any appreciable mass, however, an electric charge must either be extremely great or must be extremely concentrated; and, unless it is to be utterly masked by the matter with which it is associated, it must be the latter: that is to say, it must exist on bodies of far less than ultra-microscopic size. The mass or inertia of a charge depends upon two factors—the quantity of electricity in it, and its potential—and by concentrating a given charge on to a sufficiently small sphere, the latter factor can be raised theoretically to any value we please, and thus any required inertia can be obtained; unless a stage is reached at which it becomes physically impossible to concentrate it any more.

2. The next thesis is a very simple and familiar one, and dates virtually from the time of Faraday, though the conception has gradually gained in clearness and solidity: it is that every atom of matter can have associated with it a certain definite quantity of electricity called the ionic charge, that some atoms can have double this quantity, some treble, and so on, but that no atom or any piece of matter can have a fraction of this quantity, which therefore appears to be an ultimate unit, a sort of 'atom,' of electricity. The ratio of the charge to the weight of a material atom is measured with accuracy in electrolysis,

in accordance with what are called Faraday's laws; and in so far as the mass of the atom itself is otherwise approximately known, the quantity of electricity which can be associated with it is known with a similar degree of approximate accuracy.

3. Now mathematical data were given by J. J. Thomson in 1881 which enable us to say that if the charge of electricity usually associated with a single monad atom of matter were concentrated on to a spherical nucleus one-hundred-thousandth of an atom's dimension in diameter, it would thereby possess a mass about one-thousandth of that of the lightest atom known, viz., the hydrogen atom.

Such a hypothetical concentrated unit of electricity it has become customary to call an 'electron,' a name invented by Dr. Johnstone Stoney to designate the so to speak 'atom' or smallest known unit of electric charge. Every electric charge is to be thought of as due to the possession of a number of electrons, but a fraction of an electron is at present considered impossible, meaning that no indication of any further subdivision has ever loomed even indistinctly above the horizon of practical or theoretical possibility.

The electrification of an atom of matter consists in attaching such an electron to it, or in detaching one from it. An atom of matter possessing an electron in excess is called an 'ion'; and there is reason to know that, considered as a charged body, its charge is that which we have been historically accustomed to designate 'negative'; whereas an atom of matter with one electron in defect is that which has historically been called a 'positive' ion.

This inversion in the natural use of the names positive and negative is inconvenient but accidental and not really serious; it dates from the time of Benjamin Franklin.

These ions or traveling particles of matter have been long known. A liquid or a gas conducts because of the locomotion of its charged particles. The particles travel in an electric field because of their attached charges, all the positive going one way, and all the negative the other way; and each kind of matter possesses an intrinsic or characteristic ionic velocity, when urged by a given field through a given solution. The charges may be likened to horses or other propelling agency, and the atom to the vehicle or heavy body which is dragged along. The speed of travel through liquids is very slow, but through gases is considerably quicker, partly because there is less resistance, and partly because it is easier to maintain a steep gradient of potential in a medium where the ions are not too numerous.

The act of production of such ions is styled 'ionization,' and the process has been employed to explain very many facts in both physics and chemistry.

As an example, Röntgen rays passing through air ionize it and so render it conducting for a time: wherefore they are able readily to discharge electrified bodies, in this secondary way.

It may be convenient here to emphasize the dimensions of an electron as above specified, for the arguments in favor of that size are very strong, though not absolutely conclusive; we are sure that their mass is of the order one thousandth of the atomic mass of hydrogen, and we are sure that if they are purely and solely electrical their size must be one hundred-thousandth of the linear dimensions of an atom; a size with which their penetrating power and other behavior is quite consistent. Assuming this estimate to be true, it is noteworthy how very small these electrical particles are, compared with the atom of matter to which they are attached. If an electron is represented by a sphere an inch in diameter, the diameter of an atom of matter on the same scale is a mile and a half. Or if an atom of matter is represented by the size of this theater, an electron is represented on the same scale by a printer's full stop. It is well to bear this extreme smallness in mind in what follows.

An atom is not a large thing, but if it is composed of electrons, the spaces between them are enormous compared with their size—as great relatively as are the spaces between the planets in the solar system.

4. My next thesis is that these electrons or minute charged corpuscles can exist separately, for they can be detached from their atoms of matter at an electrode, not only in electrolytic liquids but also in gases, and when thus released from their thousandfold more massive atom, they fly away from the negative electrode with prodigious speed, because they are acted on by the same electrical propelling force as before, but now have hardly anything to move.

These isolated flying particles travel a long distance in rarefied gas, and are known as cathode rays. They were studied by Hittorf, Crookes, Lenard and others, both inside and outside vacuum tubes, and they are now known to be flung off spontaneously from many substances. When stopped suddenly by a massive obstacle, they give rise to the X-radiation discovered by Röntgen. At first these cathode rays were thought to be atoms of matter, though their extraordinary penetrating power rendered such a hypothesis difficult of belief, and caused Crookes to speak of them as matter in a fourth state. They are, however, certainly energetic bodies, being able to propel light windmills, to heat platinum to redness, and to charge an electroscope; they are also able to penetrate thin sheets of metal and to affect photographic plates or phosphorescent substances on the other side. They are not so penetrating, however, as are some of the Röntgen rays.

The final definite establishment of the fact that these flying particles are not atoms of matter, but are bits chipped off the atoms, fractions of an atom as it were, the same identical kind of bits being chipped off every kind of chemical atom, their mass always about one thousandth of that of a hydrogen atom, and moving under favorable circumstances with something not much less than the speed of light, is due to the researches of Professor J. J. Thomson and his coadjutors in the Cavendish Laboratory, Cambridge, and represents a long series of measurements devised and executed with consummate skill.

I have no time to go into detail concerning these important and elaborate and most interesting investigations. Suffice it to say that portions of them are due to your own Wykeham professor of physics, Professor Townsend, working in conjunction and collaboration with others, under the leadership of Professor J. J. Thomson; and that this whole series of Cavendish Laboratory researches may be said to constitute the high-water mark of the world's experimental physics during the beginning of this century.

5. I must not dwell upon the properties and powers of electrons, nor upon the experimental means by which these measurements were made, for it is far too large a subject. I must exhibit a few diagrams, and briefly summarize a few main facts.

Electrons have been shown to be shot off from any negatively charged body, especially from negatively electrified metals, when exposed to ultra-violet light.

When shot into a mass of air they ionize that air for a time, and render it electrolytically conducting; also of course they can discharge positively electrified bodies themselves, and can thus be most readily detected in small numbers.

Electrons in orbital motion have been shown to constitute the mechanism by which atoms are able to radiate light; and a great mass of semi-astronomical facts concerning these orbits and their perturbations have been obtained by immersing the source of light in a strong magnetic field, and observing the minute but very definite changes of spectra thereby produced: a branch of science with which the names of H. A. Lorentz, of Leyden, and Zeeman, of Amsterdam, will be inseparably associated.

In all these and other ways the electron has become a familiar object. It constitutes the ionic charge of matter. Multiples of it, but no fractions, are possible. Its mass, its charge and its speed have been frequently measured by different processes, and always with consistent results. It is the most definite and fundamental and simple unit which we know of in nature.

It has thus displaced the so-called atom of matter from its fundamental place of indivisibility. The atom of matter has been shown

capable of losing an electron, of having at least one chipped off it. The electron has been shown to possess in kind, though not in degree, the fundamental properties of the original atom of which it had formed a part; and it becomes a reasonable hypothesis to surmise that the whole of the atom may be built up of positive and negative electrons interleaved together, and of nothing else; an active or charged ion having one electron in excess or defect, but the neutral atom having an exact number of pairs. The oppositely charged electrons are to be thought of on this hypothesis as flying about inside the atom, as a few thousand specks like full stops might fly about inside this hall; forming a kind of cosmic system under their strong mutual forces, and occupying the otherwise empty region of space which we call the atom—occupying it in the same sense that a few scattered but armed soldiers can occupy a territory—occupying it by forceful activity, not by bodily bulk.

6. The hypothetical part of the statement about the size of an electron is the following. Whereas both the mass and the charge of an electron is known, it is not yet quite certain that the mass is *wholly* due to the charge. It is possible, but to me very unlikely, that the electron, as we know it, contains a material nucleus in addition to its charge, so in that case it need not be so concentrated, because a portion of its mass would be otherwise accounted for.

I say 'accounted for,' but it would be equally true to say unaccounted for. The mass which is explicable electrically is to a considerable extent understood, but the mass which is merely material (whatever that may mean) is not understood at all. We know more about electricity than about matter; and the way in which electrical inertia is accounted for electromagnetically and localized in the ether immediately surrounding the nucleus of charge, is comparatively clear and distinct.

There *may* possibly be two different kinds of inertia, which exactly simulate each other, one electrical and the other material; and those who hold this as a reasonable possibility are careful to speak of electrons as 'corpuscles,' meaning charged particles of matter of extremely small size, much smaller than an atom, consisting of a definite electric charge and an unknown material nucleus; which nucleus, as they recognize, but have not yet finally proved, may quite possibly be zero.

The chief defect in the electrical theory of matter at present is that the *positive* electron, if it exists, has never yet been isolated from the rest of an atom of matter. It has never been found detached from a mass less than the hydrogen atom; whereas the negative electron is constantly and freely encountered flying about alone, its mass being little more than the thousandth part of an atom of hydrogen.

Until a positive electron can be similarly isolated, the hypothesis that an atom is really composed solely of electricity, that is to say, of equal quantities of positive and negative electricity associated together in a certain grouping of little bodies, each of which is nothing more than a concentrated charge of electricity of known amount, must remain a hypothesis.

7. It is a fascinating guess that the electrons constitute the fundamental substratum of which all matter is composed. That a grouping of say 700 electrons, 350 positive and 350 negative, interleaved or interlocked in a state of violent motion so as to produce a stable configuration under the influence of their centrifugal inertia and their electric forces, constitutes an atom of hydrogen. That sixteen times as many, in another stable grouping, constitute an atom of oxygen. That some 16,000 of them go to form an atom of sodium; about 100,000 an atom of barium; and 160,000 an atom of radium.

On this view all the elements would be regarded as different groupings of one fundamental constituent. Of all the groupings possible, doubtless most are so unstable as never to be formed; but some are stable, or at least relatively stable, and these stabler groupings constitute the chemical elements that we know. The fundamental ingredient of which, on this view, the whole of matter is made up, is nothing more or less than electricity, in the form of an aggregate of an equal number of positive and negative electric charges.

This, when established, will be a unification of matter such as has through all the ages been sought; it goes further than had been hoped, for the substratum is not an unknown and hypothetical protyle, but the familiar electric charge. Nevertheless, of course, it is no *ultimate* explanation. The questions remain, what then is an electric charge? what is the internal structure and constitution of an electron? wherein lies the difference between positive and negative electricity? and what is their relation to the ether of space? Definite questions these, and doubtless some day answerable; indeed, powerful methods of attack on this position have been already contrived by Dr. J. Larmor and others; but they are questions of a higher order of difficulty than those which occupy us to-day, and it must remain for a future Romanes lecturer to report progress in these directions, whenever adequate progress has in fact been made.

8. That is the end of the first half of my lecture; and six months ago that, somewhat expanded, might have been the whole of it, because the next portion would have seemed too fanciful; but discoveries have been made, chiefly in France and in Canada—some of the most striking of them within the present year—which remove the treatment of the next part of my subject from the realm of fancy to the region of probability, and justify my proceeding further with some of

the theoretical consequences deducible from an electric theory of matter.

I referred above briefly to the origin of radiation, saying that by the method of applying a powerful magnet to a source of light, and examining the minute perturbations in the lines of the spectrum thus produced, it had been proved that the real source of radiation was an electric charge in rapid orbital motion; and I now go on to say that by careful measurement of the amount of perturbation it has been definitely proved that it is our friends the negative electrons, with a mass about one thousandth of the smallest known atom of matter, that are responsible for the excitation of ether waves or the production of light. Larmor and others have indeed shown mathematically that whenever an electric charge is subject to acceleration, an emission of some amount of radiation is inevitable, by reason of the interaction of its electric and magnetic fields; and it is probable that there is no other source of light or radiation possible except this change in the motion of electrons. It is known, for instance, that the violent acceleration or retardation of electrons when they encounter an obstacle is responsible for the excitation of Röntgen rays. All light, and all the Hertz waves or pulses employed in wireless telegraphy, are due to electric acceleration, and the greater the rate of change of velocity the more violent is the radiation emitted.

The charge may oscillate, as in a Hertz vibrator, or it may revolve, as in a source of ordinary light such as a sodium flame. In order to emit perceptible radiation by revolving, it must revolve with extreme speed in a very small orbit, so that its rate of curvature or centripetal acceleration may be considerable; for it is on the square of the value of the average acceleration that the energy of radiation depends.

9. All this is of the nature of a definite and certain thesis; but now we are going to apply it to our hypothesis that the atom of matter is either wholly or partially composed of electrons in a state of vigorous motion among themselves. Such revolving or vibrating electrons are subject to acceleration, either radial or tangential, and must therefore to a greater or less extent necessarily emit radiation; it becomes natural to inquire whence comes the energy that is radiated away.

Now in ordinary familiar cases it is the irregular agitation of molecules which we call 'heat' that is being radiated away; and in that case the result is a mere cooling, or diminution of the molecular agitation, which can readily be made up by receipt of similar energy from the enclosures or from surrounding bodies; or, if not made up, it can produce the ordinary well-known effects of 'cold.' But to the motion of the internal parts of an atom the ideas of heat and temperature do not apply. The atom, if it lose energy, must lose what is to it an essential ingredient; and hence this inevitable radiating power

of the constituents of an atom seemed to constitute a difficulty, for it suggested that an atom of matter was not really a permanent and eternal thing, but that it contained within itself the seeds of its own decay and ultimate dissipation into the separate electrons of which it was composed. The process might indeed be exceedingly slow, the radiation loss might be almost imperceptible, but, in so far as an atom is composed of revolving electrons, it is inevitable that radiation of energy must go on from it, and that this must in the long run have some perceptible degenerative result.

10. That result has quite recently, I believe, been experimentally discovered, and is a part of the phenomenon known as 'radio-activity.'

So now we come to the most remarkable and probably the most interesting step of all.

The phenomenon of spontaneous radio-activity, discovered first by Becquerel in uranium and thorium, and greatly extended by the brilliant chemical researches of M. and Mme. Curie which resulted in the discovery of radium (they are coming to London next week, and will be received, I expect, royally by the scientific world), was at first supposed to consist in the emission of a sort of X-rays or ether pulses; and was subsequently assumed to consist chiefly in the bodily emission of electrons, which were shot off from the radio-active substance as they are from a negative electrode in a vacuum-tube, or as they are in air when ultra-violet light falls upon clean negatively charged surfaces.

As a matter of fact both these modes of radiation—the wave form and the corpuscular form—are emitted by radio-active bodies, but they turn out to be of subordinate importance, and must be regarded as secondary or subsidiary results of the main phenomenon.

The main fact of radio-activity has been shown by Professor Rutherford, of Montreal, in a paper published in the month of February this very year, to consist in the flinging away with great violence of actual atoms of matter: atoms electrified indeed, but not negatively like electrons, and not small or penetrating like them, but full-sized atoms, such as are easily stopped by a thin sheet of metal, or even by a sheet of paper—atoms which are positively charged and possessed of a remarkable amount of energy, ionizing the air which they bombard to an extraordinary extent, and likewise generating quite a perceptible amount of heat wherever they strike; producing indeed a flash when they strike a suitable target, as Crookes has shown, quite like the impact of a cannon-ball on an armor-plate. Their speed, indeed, far exceeds that of any cannon-ball that ever existed, being as much faster than a cannon-ball as that is faster than a snail's crawl; a hundred times faster than the fastest flying star, these atomic projectiles constitute the fastest moving matter known. This furious

bombardment from a radio-active substance continues without intermission and apparently without sign of diminution or cessation. There is every reason to believe that a minute scrap of radium, scarcely perceptible to the eye, may go on emitting these energetic projectiles for hundreds of years.

11. At first sight the fact that it is merely atoms of matter which are being flung off by most radio-active substances, and that ethereal and other effects are subsidiary to this emission of substance, seems to lessen the interest attaching to the phenomenon, reducing it to something of merely chemical importance, and suggesting a resemblance to scent or other volatilization from solid bodies. But Professor Rutherford, with great skill, succeeded in determining approximately the atomic weight of the utterly imperceptible amount of substance thrown off, as well as its speed, and found that it was not by any means the radio-active substance itself which was evaporating, but something quite different.

Plainly, if an elementary form of matter is found to be throwing off another substance, it becomes imperative to inquire what that substance is, and what it is that is left behind. Now the atomic weight of radium, or of thorium or uranium, or of any known strongly radio-active substance, is very high, in each case over two hundred times the atomic weight of hydrogen, whereas the atomic weight of the substance flung off appears to be more nearly of the order one or two; in other words, the substance thrown off is more likely to be either hydrogen or helium than it is likely to be radium. It is just possible that the inert chemical elements are by-products of radio-activity.

Now clearly here is a fact, if fact it be, of prodigious importance. Undoubtedly the measurements require confirmation, but for myself I see no reason to doubt them, at least as regards their order of magnitude. The atomic weight of radium being say 225, and that of the projected portion being say 2, the residue must represent by its atomic weight the difference between the heavy atom of the original substance and that of the light atom or atoms which have been flung away: unless indeed it be assumed, as it will almost certainly be assumed by some skeptical chemists, those who derided argon and other chemical discoveries when made in a physical manner, that the substance flung away is some foreign ingredient or impurity—a hypothesis, I venture to say, already strongly against the weight of available evidence.

The substance left behind in the pores of the radio-active substance has been examined even more completely than the projected portion: it is volatile, it slowly diffuses away, and it behaves like a gas. It can be stored in gas-holders when mixed with air, for in amount it is quite imperceptible to all ordinary tests; and yet it can be passed through pipes and otherwise dealt with. It condenses not far above the tem-

perature of liquid air, and it is itself radio-active, but in such a way that its power decays rapidly with time. Its radio-activity seems to consist likewise in throwing away part of itself and leaving yet another residue, likewise radio-active; and one of the residues so left seems ultimately to pitch away electrons simply instead of atoms of matter. It is not to be supposed that thorium and radium and uranium all behave alike in details. The emanation of one may lose its activity rapidly, and give rise to another substance which retains its power for some time; the emanation of another element may last some time and generate a substance whose activity rapidly decays; but into these details it is not now the place to go.

12. Assuming the truth of this strange string of laboratory facts, we appear to be face to face with a phenomenon quite new in the history of the world. No one has hitherto observed the transition from one form of matter to another: though throughout the Middle Ages such a transmutation was looked for. The transmutation of elements has been suspected in modern times on evidence vaguely deducible by skilled observers from the spectroscopic details of solar and stellar appearances. The evolution of matter has likewise been suspected by a few chemists of genius: it was perceived, on the strength of Mendelejeff's law, that the elements form a kind of family or related series, and it was surmised that possibly the barriers between one species and the next were not absolutely infrangible, but that temporary transitional forms might occur. All this was speculation; but here in radio-active matter the process appears to be going on before our eyes. Professor Rutherford and Mr. Soddy, who in Canada during the present year have worked hard and admirably at the subject, have adduced facts which point clearly in this direction; and they initially describe what appear to be the first links of a chain of substances, all produced in hopelessly minute quantities reckoned by ordinary tests, but which yet by electrical means can easily be detected, and their boiling-points and other properties investigated. Moreover, the investigators of these strange substances are able to dissolve and precipitate, and perform ordinary chemical operations on, these utterly imponderable and hopelessly minute deposits of radio-active substances, because of the powerful means of detection which their ionizing power puts into our hands —even a few stray atoms being able by their ionizing power to discharge an electroscope appreciably.

13. Thus then it would appear that our theoretical conclusion concerning the inevitable radiation and loss of energy from electrically constituted atoms of matter, a loss which must involve them in necessary change and dissolution, meets with quite unexpectedly rapid confirmation, and it is for that reason that I feel willing to accept tentatively and as a working hypothesis this explanation of radio-activity.

It represents a fact previously wanted on theoretical grounds. For how is radio-activity to be explained? It looks as if the massive and extremely complex atoms of a radio-active substance were liable to get into an unstable condition, probably reaching this condition whenever any part of it attempts, or is urged, to move with the velocity of light. I have shown elsewhere* that the mere fact of radiation will act as a resisting medium and increase the speed of the particles automatically, on the same principle that a comet would be accelerated if it met with resistance; since the inverse square law applies to electrical central forces. Electrical mass is not strictly constant: it is a function of speed, but in such a way that it is practically constant until the velocity of light is very nearly attained. That is a critical velocity, which apparently can not be surpassed. When this critical speed is reached, any electrified body becomes suddenly of infinite mass, and something is bound to happen. What that something is, it is not easy theoretically to say; but the partial or incipient disintegration or dissociation of the atom, and the flying away of a portion with a speed comparable to that of light, is no unlikely result.

Out of the whole multitude of atoms, even of the atoms of a conspicuously radio-active substance, it is probable that only a very few get into this unstable or critical condition at any one time; perhaps not more than one in a million million; nevertheless, just as occasional though rare encounters take place in the heavens, followed by the blaze of a new and temporary star, so, though probably not by the same mechanism, here and there a few out of the billions of atoms in any perceptible speck of radium arrive in due time at the unstable condition, and break down into something else, with energetic radio-activity during the sudden collapsing process; emitting in the process of collapse not only the main projected substance, but likewise also a few electrons and those X-rays which always accompany a sudden electric jerk or recoil. And the X-rays so emitted are of the most penetrating kind known, being able to pass through an inch of solid iron in perceptible quantity.

14. The hypothesis concerning radio-activity which is now in the field, then, is that a very small number, an almost infinitesimal proportion, of the atoms are constantly breaking up; throwing away a small portion, say one per cent. of themselves, with immense violence, at about one tenth of the speed of light; the remainder constitute a slightly different substance, which, however, is still extremely unstable, and therefore radio-active, going through its stages with much greater rapidity than the radium itself, because practically the whole of it is in the unstable condition, and so giving rise to fresh and fresh products

* See *Nature* for June 11, 1903.

of its own decay, till a comparatively stable state is reached, or till the process passes beyond our means of detection.

Roughly, the process may be likened in some respects to the condensation or contraction of a nebula. The particles constituting a whirling nebula fall together until the centrifugal force of the peripheral portions exceeds the gravitative pull of the central mass, and then they are shrunk off and left behind, afterwards agglomerating into a planet; while the residue goes on shrinking and evolving fresh bodies and generating heat. A nebula is not hot, but it has an immense store of potential energy, some of which it can turn into heat, and so form a hot central nucleus or sun. A radium atom is not hot, but it too has a great store of potential energy, immense in proportion to its mass, for it is controlled by electrical, not by gravitational forces; and just as the falling together of the solar material generates heat, so that a shrinkage of a few yards per century can account for all its tremendous emission, so it has been calculated that the collapsing of the electrical constituents of a radium atom, by so little as one per cent. of their distance apart, can supply the whole of the energy of the observed radiation—large though that is—for something like 30,000 years.

15. It does not follow that the life of a piece of radium is as great as that; the data are uncertain at present, but there is absolutely no ground for the popular and gratuitous surmise that it emits energy without loss or waste of any kind, and that it is competent to go on for ever. The idea, at one time irresponsibly mooted, that it contradicted the principle of the conservation of energy, and was troubling physicists with the idea that they must overhaul their theories—a thing which they ought always to be delighted to do on good evidence—this idea was a gratuitous absurdity and never had the slightest foundation; but the notion that radium was perhaps able to draw upon some unknown source or store of energy, without itself suffering loss, was a possibility which has not yet wholly disappeared from some minds. Sir W. Crookes, for instance, suggested that it might somehow utilize the most quickly moving atoms of air, after the fashion of a Maxwell demon—a possibility that should always be borne in mind as a conceivable explanation of the power of some living organisms. It is much more reasonable to suppose, however, that radium and the other like substances are drawing upon their own stores of internal atomic energy, and thereby gradually disintegrating and falling into other, and ultimately into more stable, forms of matter.

Not that it is to be supposed that even these are finally and absolutely stable: these too are subject to radiation loss, and so must be liable to decay; but at a vastly slower rate, perhaps not more than a few hundred atoms changing and diffusing away each second—a process

utterly imperceptible to the most delicate weighing until after the lapse of millions of years; so that for all practical purposes, and for times such as are dealt with in cosmic history, they are permanent, even as the solar system and stellar aggregates appear to us to be permanent. Yet we know that all these systems are in reality transitory, as terrestrial structures like the pyramids or as the mountains and the continents themselves are transitory: of all these things it may be said that in any given form they have their day and cease to be. But whereas geological and astronomical configurations pass through their phases in a time to be reckoned in millions of years, the active life of a solar system covering perhaps no very long period, it is probable that the changes we have begun to suspect in the foundation stones of the universe, the more stable elemental atoms themselves, must require a period to be expressed only by millions of millions of centuries. For in such a time as this, at the rate of a hundred atoms per second, a bare kilogram—a couple of pounds only—of matter, even of heavy matter, would have drifted away; not so much indeed—a couple of ounces more likely. And yet this period is a million times the estimated age of the earth.

16. If we allow ourselves to speculate, on the strength of the slender experimental evidence as yet forthcoming, instead of waiting, as to be wise we must wait, for confirmation and thorough examination of the facts, we should say that the whole of existing matter appears liable to processes of change, and in that sense to be a transient phenomenon.

Somehow, we might conjecture, by some means at present unknown, it takes its rise: electrons of opposite sign crystallizing or falling together, perhaps at first into a manifestly unstable form; these forms then pass on from one into another, going through a series of transitional states, and abiding for a long time in those configurations which are most stable; giving a process of evolution inconceivably slow in its later stages, comparatively rapid in its early ones: and yet not so rapid, even in a substance like radium, but that its life as such may be reckoned by thousands of years.

If such a transitory existence is ever established for the forms of matter as we know them, it by no means follows that the process goes on in one direction only, or that the total amount of matter in the universe is subject to diminution. There may be regeneration as well as degeneration.

The total amount of radio-activity in a substance is singularly constant. If the radio-active portion is removed, a fresh supply makes its appearance at a measured rate, that rate being expressible by a decreasing geometrical progression, and being precisely equal to the rate at which the power of the removed portion decays.

Whether the total amount of matter in the universe is constant likewise, as much disappearing at one end by resolution into electrons as is formed at the other end by their aggregating together, is at present quite unknown; and indeed it is clear that we have now become far immersed in the region of speculation. Nevertheless, it is speculation not of an illegitimate character, for it is very consistent with all that we know about the rest of the material universe.

Astronomy tells us that the cosmic scheme, though it looks permanent, is subject to constant flux. In the sky we see solar systems and suns in process of formation by aggregation out of nebulæ; we see them rise in brilliancy, maintaining a number of planets in health and activity for a time, and then slowly become subject to decay and death. What happens after that is not certainly known; it may be that by collision a nebula may be reconstituted and the process started again; though so long as there is only a force of one sign at work (gravitation only) it would seem that ultimately the regenerative process must come to an end. The repellent force exerted by light upon small particles, however, must not be forgotten; it can overcome gravitation when it acts on small enough bodies; and there are other possibilities. Among the parts of an atom certainly the forces are conspicuously not of one sign; inside an atom there exist both attractive and repulsive forces; the resolution of an atom into its electron constituents, and the aggregation of these constituents into fresh atoms, are both perfectly thinkable. All we have to do is to ascertain by careful and patient investigation what really happens; and my experience has led me to feel sure of this, that whatever hypotheses and speculations we may frame, we can not exceed the reality in genuine wonder; and I believe that the simplicity and beauty of the truth concerning even the material universe, when we know it, will be such as to elicit feelings of reverent awe and adoration.

THE TRAINING OF A PHYSICIAN.*

By President DAVID STARR JORDAN,

LELAND STANFORD JR. UNIVERSITY.

IN mediæval times the physician was a compound of sorcerer and priest; distrusted by sorcerers lest he disclose the secrets of their trade; distrusted by priests lest he undo their work with the heathenism of sorcery. His operations were mystic, out of relation to cause and effect, for it was widely believed that the forces of the body are independent of bodily structures, and that sickness was a blow from the outside, a penalty for sin or lust or unbelief, not the expression of bodily derangement.

So the physician dealt with words as much as with medicines. Many Latin words held a magic power. By their use he could call up spirits, mostly evil, could put man to sleep or make a broomstick alive. Lest he carry these things too far, there were statutes forbidding the physician to act save in the presence of a priest. Besides words, he dealt in simples; each drug having potency over its particular disease. These drugs he would know by their signatures, the mark of the Almighty on them indicating their use. Thus a scrofulous-looking root would cure scrofula, snake-head or snake-root would cure snake bite; blood-root with red juice was good for the blood; celandine with yellow juice was marked for jaundice; liver-wort with liver-shaped leaves would heal the liver; eye-bright with an eye-spot in the flower would heal the eyes; bear's grease from hairy bears would cure baldness; a hair of the mad dog would relieve its venom. A red rag would cure inflammations. A drug which would give a headache would cure it. A long series of fancies and superstitions, which find their natural continuance in the electric belts and patent medicines of to-day.

Surgery was despised by medicine, and the little which was practised fell to the lot of barbers; with dirty knives and reckless hands surgery ended in gangrene and blood poisoning.

The success of the physician lay largely in the mystery of his operations, his Latin words and the red and blue flames which danced about the broths he concocted.

Meanwhile sanitation and diet were regarded as contrary to religion. Even the taking of medicine was sometimes forbidden as being a scheme to thwart God's purposes. Besides all this, the words

* Abstract of address, Cooper Medical College Commencement.

of the great physician, Galen, became the court of final appeal, and his ignorance marked the limit of all medical knowledge.

Yet there were great physicians in those days, martyrs and saints who should rank with the noblest, men who tried to know the truth and to act in accord with it. Roger Bacon was on the verge of discovering the secret of contagious disease and its prevention by inoculation and sanitation. Fourteen years in prison prevented all this.

Vesalius in these days was the founder of anatomy. Dissection of human bodies was prohibited as sacrilegious, the work of sorcerers and dangerous, as the supposed resurrection bone, the nucleus of the rising body, might be injured or destroyed by careless handling. Vesalius haunted gibbets and charnel houses, for the waste of human bodies. He hoped especially to find through dissection the secret of the Black Death. The personal physician of Charles V., he had powerful protection in his early work, but he fell at last under the mean bigotry of Philip II. "He was not lost," says President White. "In this century a great painter has again given him to us. By the magic of Hamann's pencil Vesalius again stands on earth and we look once more into his cell. Its windows and doors, bolted and barred within, betoken the storm of bigotry which rages without; the crucifix, toward which he turns his eyes, symbolizes the spirit in which he labours; the corpse of the plague-stricken beneath his hand ceases to be repulsive; his very soul seems to send forth rays from the canvas, which strengthen us for the good fight in this age."

Those who destroyed Vesalius did so in the name of religion. It was believed that 'diseases are sent as punishment; who interferes with them breaks God's commandment and is God's enemy.'

This belief checked the growth of medicine even so late as fifty years ago when Simpson first used anæsthetics in obstetrics. This was held to violate the command: 'In sorrow shalt thou bring forth children.' To doubt the prevalent theory of disease was to doubt all religion and to be a foe to Christianity. No wonder there were physicians who doubted; no wonder that it was declared on high authority: 'When three physicians meet, there are two atheists,' if by atheist was meant all who believe that diseases are produced by natural causes.

So long as medicine rested on a basis of mystery, symbolism and philosophy, its limits set by the words of Galen, so long its progress was marked by martyrs, not by its successful practitioners. Even a hundred years ago success in medicine was largely quackery. Imaginary diseases were treated and in fantastic ways. In Napoleon's time, the itch was a prevalent disease in the higher classes, a disease which they did not know how to cure. At this time, most internal ills were diagnosed as 'Gale repercutée,' 'Itch struck-in,' and the arch

medical performer of his time, Hahnemann, is reported to have said that two thirds of all diseases have this origin, 'they are the itch struck-in.' But a little knowledge of entomology with a hand lens has abolished the disease. Itch no longer 'strikes in' and nothing is more easily cured. Meanwhile the internal disorders called itch are being treated each in its own way.

The progress in medicine has been in proportion to its dependence on science and the scientific method. Science is human experience tested and set in order. Progress through science means simply learning through experience and taking pains to sift and test experience.

I need not speak of the details of this progress. Surgery is applied anatomy; antisepsis is applied bacteriology; pharmacology is applied chemistry; with instruments of precision, wonderful progress is made in the interpretation of experience. There is nothing in the history of science more suggestive than the simultaneous lights thrown on bacteria and microbes from many quarters at once. Lister with his clean knives and antiseptic surgery, Bastian trying to prove the spontaneous generation of infusoria in vegetable broths; Tyndall trying to clear his tubes from floating particles in the air which break up the rays of light, Pasteur with his blighted silk-worms—all these men were at work at the same problem—each with his varied instruments of precision, and the final result of all, the theory of fermentation, putrefaction, antisepsis and contagious diseases. Our knowledge of the minute organisms all about us, as real, as helpful or as harmful as the larger creatures of the earth, but the whole beyond the reach of the unaided senses.

With this knowledge, we have a new birth of the art of medicine. When we know our enemies, we can fight them intelligently. The progress of medicine, its achievements and discoveries being granted, how shall we teach it?

There should be advance in methods of teaching as well as in methods of gaining and testing facts. In the old days we had the method of apprenticeship. The little doctor saw what the big one did and followed his method. He learned to say the magic word, to make the magic passes, to brew the magic drug, to say more than he knows and to know more than he says.

In the ancient universities, the lecture was an exercise in dictation, the student taking word for word the wise phrases of the master. The ancient wizardry still prevails in some of our forms of medico-religious healing; the ancient belief in simples and signatory remedies, in our patent medicine trade. With ignorant people, the mysteries of

ignorance are valued above wisdom. To value wisdom is already to be wise.

The physician of to-day is not a priest nor a sorcerer. His place is rather that of an engineer. One who understands the make-up of the human mind machine, tries to keep it in order and faithfully repairs it when its parts are out of place. He knows that each effect has a cause, none the more mysterious because it must be sought with instruments of precision. He regards pain as a warning, not as a punishment. It is a sign that a screw is loose somewhere, and were it not for this warning we should not be sure to make it good.

In the continental universities of Europe, the teaching of medicine has been from the first a university function. The faculty in medicine has been one of the primary divisions of the university. The teaching of medicine has kept pace with the instruction in law, philosophy and science, under the same general influences, and with the same methods of control. In England, medical instruction has been more or less divorced from the university. It has been rather a function of medical associations and hospitals.

The American college had its origin in English models. Like the colleges of Oxford and Cambridge, it was more or less under ecclesiastical control, its first purpose being to develop clergymen and gentlemen, professional training being outside its scope and purpose. Thus the medical school in America arose through associations of physicians, wholly apart from the college system.

But the same argument which justifies common schools, high schools and state universities at public expense, applies to medical schools also. It is cheaper for a state, and infinitely better for it, to educate its own physicians than to tolerate uneducated ones. Better to educate its doctors and hire them afterwards than to be the prey of the quack, the impostor, the nostrum vendor and the almanac. This was the view of the founders of the University of Michigan, the first state college to devote itself frankly to the service of the state, regardless of tradition, regardless of what other states and institutions may be doing.

Other states followed the example of Michigan, establishing schools of law and medicine and of other professions. Still others, as Indiana, adopted a contrary view, and for a time refused to appropriate money to 'help young men into these easy professions.'

Meanwhile, in default of endowment and public support, private interest founded medical schools where they were needed. Later, for purposes of advertising or of money-making, other schools of lower standards were established where they were not needed. Hence we have finally medical schools of every grade of honor and of dishonor,

some ranking with the best in the world, others periodically raided by the police.

Our democratic custom is to let every school shift for itself. In the eyes of the law, every doctor is a doctor, if he has earned or bought a diploma somewhere—herb-doctor, corn-doctor, faith-healer, electric-healer, all kinds of healers, pass as doctors, and the people must choose for themselves.

Doubtless science wins in the long run. The honest school and the honest man are the final winners, but there is a prodigious amount of waste and suffering before the public knows the difference between surgeons and bloodsuckers.

More and more the honest medical schools are brought into touch with the university. Around the university the tested educational machinery tends to center. Sound instruction in medicine demands a broad base of science—physiology, anatomy, chemistry, histology, bacteriology and above all the methods of scientific research. All these are fundamental to any real knowledge of the art of medicine. All these are essentials in the work of the modern university. The medical school is giving these up to the institutions which can teach them for their own sake, and therefore teach them better. This change shortens the medical course, by making it longer, by placing it on a broader and higher foundation. The medical school, then, teaches the application of science, the science itself being studied elsewhere. There is a tendency toward an easy transition from the one to the other, so that the student can not tell when he began to study medicine.

In the old days the transition was abrupt, and the medical student learned applications of science before he had the faintest idea of science itself. He was thrown at once into a topsy-turvy world, where decencies did not count, where grewsome honors were everyday affairs, and where all ordinary restraints were cast aside. Hence he kept his tobacco in the skull of a murderer, wore a resurrection bone for a scarf-pin, and was the most reckless, lawless, irreverent of all students, careless of temperance, sanitation and chastity. Of all students, thirty years ago, the medical student had deservedly the reputation of being the worst.

Leaving out ill-equipped or temporary schools, the American medical school of the future will have one or the other of two great purposes. The one is typified perhaps by the Medical School of Michigan. It will take the profession as it is and raise it as a whole. So many men will be doctors, so many will be lawyers in Michigan. Let us take them as we find them and make them just as good lawyers and doctors as we can. Let us not drive them away by requirements they can not or will not meet, but adjust the work and conditions to the

best they can meet, the best standards winning in the long run and carrying public opinion with them.

The other ideal is perhaps typified by Johns Hopkins University. Let the university medical school deal with the exceptional man of exceptional ability and exceptional training. Give him special advantages; send out a limited number of the best physicians possible, and raise the standard of the profession by filling its ranks with the best the university can send.

The one ideal or the other will be, consciously or not, before each professional school which strives to be really helpful. It is not for me to say which is best. The one purpose naturally presents itself to state institutions, or to institutions dependent on appropriations or patronage. The other is more readily achieved by institutions of independent endowment. It is a matter of economy that all schools should not be alike in this respect.

What should be the regular requirement for entrance to the medical school? The university influences tend to push requirements up. The influence of the counting room and the desire to show numbers tend to push them down. Shall men go into medicine from the common school, from the high school; from the middle of the college course; from its end? Or shall we, with Johns Hopkins, demand not only a college course, but one which contains all the sciences fundamental to the study of medicine.

For the second type of schools, the schools which aim at the highest professional success, the latter is the natural requirement, the only one worth considering. For the schools which would elevate the profession as it is, the facts must be met half way. We know that a common school preparation is farcical, yet great physicians have been made with this as the basis of education. Such are men who can learn from their own experience and interpret the experience of others. No matter how wide the door of the colleges, there are some men so strong as to be capable of educating themselves.

The high school course gives a certain breadth of culture. The high school of to-day is as good as the college of forty years ago, so far as studies go. It misses the fact of going away from home and of close relation with men of higher wisdom and riper experience than our high schools demand in their teachers.

It takes a broader mental horizon to be a physician than merely to practise medicine. For those who want the least education possible, they can get along with very little; they can omit the college. But for large-minded, widely competent men, men fit for great duties, not a moment of the college course can be spared. Whether to take a college education or not, depends on the man—what there is in him—

and on the course of study. There is no magic in the name of college, and there is no gain in wrong subjects, work shirked, or in right subjects taken under wrong teachers. Studies, like other food, must be assimilated before they can help the system.

The great indictment of the college is its waste of the student's time; prescribed studies taken unwillingly; irrelevant studies taken to fill up, helpful studies taken under poor teachers, any kind of studies taken idly—all these have tended to discredit the college course. Four years is all too short for a liberal education, if every moment be utilized. Two years is all too long if they are spent in idleness and dissipation, or if tainted by the spirit of indifference.

The spirit of the college is more important than the time it takes. The college atmosphere should be a clean and wholesome one, full of impulses to action. It is good to breathe this air, and in doing so, it matters little whether one's studies be wholly professional, half professional, or directed towards ends of culture alone.

The practical evolution of this matter will be this: The medical school for the exceptional student will require a college course of science with physiology and chemistry as the leading subjects, other sciences, with German and French, being necessary factors. The state medical colleges and those of similar purposes will content themselves with a minimum of two years of college work, along semi-professional lines, the preparatory medical course.

In city colleges where the students live at home, traveling back and forth on street cars, a college atmosphere can not be developed. In these institutions, as a rule, the college work is perfunctory, its recitations being often regarded as a disagreeable interruption of social and athletic affairs. As a rule, higher education begins when a man leaves home to become part of a guild of scholars. The city college is merely a continued high school, and with both students and teachers there is a willingness to cut it as short as possible, so that the young men can 'get down to business.' In institutions of this type, the professional school forms a sharp contrast to the college in its stronger requirements and more serious purpose. In other types of college, it is the general student who does the best work. In many of them the professional departments are far inferior in tone and spirit to the general academic course.

It becomes, then, a question of the college itself, how long a student should stay in it. If the academic requirements are severe, just and honest, if the idler, the butterfly, the blockhead and the parasite are promptly dropped from the rolls, if the spirit of plain living and high thinking rules in the college, the student should stay there as long as he can, and if possible take part of his professional work under

its guidance. The nearer the teacher, the better the work. The value of teachers grows less as the square of their distance increases. If the college course is a secondary matter, with inferior teachers talking down to their students lessons prescribed because the faculty cares too little for the individual man to adapt its courses to his needs, an atmosphere of trifling, or no atmosphere at all, the sooner the student gets into something real, the better. A good university may develop in a great city, a good college can not, because teachers and students are all too far apart.

In this matter the college degree is only an incident. It is the badge of admission to the roll of alumni, a certificate of good fellowship, which always means a little and may imply a great deal. But the degree is only one of the toys of our educational babyhood, as hoods and gowns represent educational bib and tucker. Don't go out of your way to take a degree. Don't miss it because you are in too great a hurry. For the highest professional success, you can afford to take your time. It takes more provision for a cruise to the Cape of Good Hope than for a trip to the Isle of Dogs.

AMERICAN TITLES AND DISTINCTIONS.

By Professor W. Le CONTE STEVENS,

WASHINGTON AND LEE UNIVERSITY.

THOMAS CARLYLE is credited with the statement that England has a population of twenty or thirty millions—'mostly fools.' The definition of fool is not given. If the word means anything else than an expression of dislike it is that the unfortunate man who bears such a title is so deficient in intelligence or in good judgment as to be worthy of unenviable distinction. But a distinguished man, whether his distinction be good or bad, stands out among his fellows in some way. It is impossible for the larger part of any mass of human beings composing an organized body, whether the students of an educational institution, or the devotees of fashionable society, or the population of a great nation, to be distinguished. The mere fact that in such a body a majority possesses qualities which might otherwise confer distinction upon an individual destroys the possibility of preeminence based on such possession. Every one recognizes that Carlyle's epigram expressed no objective truth, but that he displayed only the acidity and peevishness of one whose influence was perceptibly waning.

Epigram is never quite consistent with truth. It may contain enough mixture of truth with falsehood to command the momentary assent of even a thoughtful man. Its essential feature is brightness rather than solidity, and it arrests the attention when accuracy fails to attract. A French writer who has recently passed away, Paul Blouët, visited America some years ago, and the inevitable book of impressions was the natural consequence. His fondness for epigram had amused many readers of a previous book entitled 'John Bull and his Island.' The first chapter of 'Jonathan and his Continent' began with the following words in imitation of Carlyle: 'The population of America is sixty millions—mostly colonels.' In a subsequent chapter he emphasized this idea with the statement, "Every American with the least self-respect is colonel or judge; but if you should discover that your interlocutor is neither colonel nor judge, call him 'Professor,' and you are out of the difficulty." This implication that professors belong by exclusion to a class without the least self-respect may be unwelcome to some of the unfortunates who are compelled to carry this mark of Cain; but there is enough truth in the Frenchman's epigram

to suggest the question whether democratic America is not the richest in titles of any country in the world; and, if so, why should it be so?

Let an American visit Germany or Russia; any country of continental Europe where the encroachment of free institutions upon the military control of society is less marked than among our people. The first feature that obtrudes itself is that soldiers in uniform are to be seen in every important town. The visitor is required to register at police headquarters and answer a variety of questions, rational and irrational, about his present, past and probable future. He learns that titles of all kinds, but especially military titles, are protected by law. The man who calls himself a colonel, or allows his friends to call him so, is soon required to prove his claim to the title. Where is his uniform? If he is a foreigner, why did he not report his rank at the police registration office? Is he not a suspicious character whose actions must be watched? If he is a native jackdaw trying to wear borrowed plumage he is lucky if he avoids arrest. The professor, moreover, is an officer of the government, whose salary is paid from the public treasury, so far as his income is derived from a salary. Any one who assumes the title without official sanction does so at his own peril. To hold such an office is presumptive evidence of marked ability, and it carries with it a claim to social deference that is universally accorded. No colonel or professor in Germany can exist as such without having stood tests of special training that prove him an educated man. No such title comes by inheritance or courtesy. It means much and its value is great. No such prize can be stolen by the unworthy, for danger attends the violation of law where popular sentiment sustains the military power that ensures its enforcement.

It must not be inferred, however, that all titles in continental Europe have retained the meaning or the importance originally attached to them. Everything depends upon the consideration whether the title has been directly acquired or has been inherited. In a German university where the present writer spent some time the physical laboratory assistant, whose duties were exclusively mechanical, was a count whose inheritance seemed to be limited to his title. In the duchy of Mecklenburg a traveler has found a count for landlord of the village inn, a countess for landlady, young counts filling the places of hostler, waiter and bootblack, and countesses for cooks and chambermaids. Indeed, in one village all the inhabitants except four were found to be of noble birth. America therefore has by no means a monopoly of cheap titles.

It would perhaps be interesting to trace in detail the evolution of titles with the development of society; but such a field is too extensive. Originally a name or title was merely the suggestion of an association. 'Young-man-afraid-of-his-horse' was a Sioux Indian whose fame might

have been local only had he not come too near to the American newspaper correspondent. The desire of the weak to appease or flatter the strong has been the most fertile origin of titles. In darkest Africa the king is addressed by such names as the 'Lion of Heaven,' the 'Bird who eats other birds,' or 'Thou who art as high as the mountains.' A proper name easily becomes applied to a family or a class, and is thus handed down to successive generations. Nothing is easier for the savage than to apply superhuman attributes to a successful warrior and to deify him after his death. After natural slumber he wakes with renewed strength. The slumber of death seems merely deeper and longer than usual, and it is easy to believe that latent power has not been lost. The warlike father of his tribe is transformed into the god of his tribe. The grand lama of Thibet does not wait for death, but is worshiped as 'God the Father' by his obsequious subjects. The ruler, whether visible or invisible, is 'father,' 'king' or 'God,' indifferently. If his authority becomes widely recognized, if his empire includes subordinate kingdoms like that of the German Kaiser to-day, he becomes 'king of kings' and 'lord of lords.'

With the development of successive grades of honor, power and position comes the demand for recognition to be accorded by those below and the temptation to appease and flatter those above. The fundamental motive is the lively sense of favors to come; the wish to create obligation among those whose power enables them possibly to interfere with our welfare, and to exact allegiance from those whom we may possibly use for our own advantage. The ordinary father of a family addresses the king in the language of adulation, and is addressed in similar terms by his wives, children and servants; while these in turn receive from the dogs all the flattery that can be ostentatiously suggested by wagging tails and eloquent barking.

But while selfishness is one of the bases of title-giving, it is not the only one. Regard for others is a characteristic of humanity quite as natural and universal as self-regard. Selfishness and generosity are relative terms. The man or woman who is much less considerate of the rights of others than are the majority of people composing society is soon found out and becomes an object of dislike, if not of positive hatred. To be kind to one's friends, to take an interest in the welfare of those around us, to help those who are in trouble, to sympathize with the pleasures of those who are enjoying life, to make friends by being friendly—these are some of the most fertile sources of human happiness. Nor is this confined to humanity. If happiness can be judged by its visible manifestations, there is many a dog whose happiness is apparently bound up in the most unselfish devotion to his master. Love in the home circle and politeness in general society are not merely indications of refinement; they are positive contributions to the general

welfare of the race. Every one understands that social usage often suggests words, phrases and sentences which imply more or less covert flattery. Indulgence in them is not only pardonable, but often demanded by an unwritten law, even if they are not accordant with the severest requirements of truth. They give pleasure without really deceiving; they excite laughter without derision; they hide sorrow; they brighten life. Much title-giving has been the outcome of an unselfish desire to express appreciation and good will. It may not be wise, but it is a good-natured attempt to give pleasure by covert flattery.

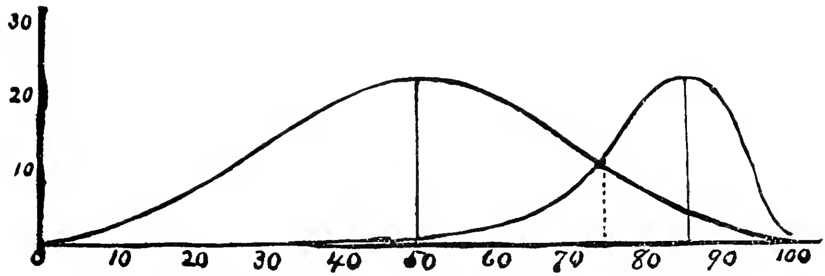
This unselfish basis for the giving of titles constitutes a sufficient explanation of that gradual diffusion and degradation of all distinctions that time invariably develops. A familiar example to all who have had experience in educational work is found in the class-room marking system, by which distinctions are based upon attainment in scholarship. Nearly a century ago the trustees of an academy well known in Virginia prescribed for the teachers a system of marking which was made up of three degrees of merit, *bonus, melior, optimus,* and three of demerit, *malus, pejor, pessimus.* If we apply to this the mathematical principle forming the basis of the theory of probabilities, it is easy to show that about 30 per cent. of all students examined ought to be graded *bonus,* and the same percentage *malus,* the sum of these two groups forming thus nearly two thirds of the whole. About 16 per cent. should be graded *melior* and the same percentage *pejor;* not quite 4 per cent. *optimus* and the same percentage *pessimus.* But what was the actual working of the system? The historian, Henry Ruffner, says: "The continual tendency was to mark inferior scholars too high. Thus it came to pass that not half the bad scholars got *malus,* the worst almost never fell below it, and *bonus,* though a mark of approbation, came to be considered as a disgrace, while *optimus* which ought to have been reserved for scholars of the highest merit, was commonly bestowed on all who rose above mediocrity." When Dr. Ruffner in 1829 became temporary president of the college into which this academy had developed, he secured the abolition of the discredited marking system, and the substitution of three grades: 'Disapproved,' 'Approved' and 'Distinguished.' According to the mathematical theory about 60 per cent. should have been approved, about 20 per cent. disapproved and 20 per cent. distinguished. But he writes that 'within two or three years some bad scholars were approved, and good scholars were nearly all distinguished.'

This continual temptation to grade as many as possible in the highest class is by no means based on selfishness alone, or even to any large extent on selfishness, though personal pride is one element. It is impossible for an examiner to make an exact numerical statement of

a mere judgment of merit. Since the estimate is confessedly only approximate, the student receives the benefit of every uncertainty. If any mistake has to be made, let him be encouraged by a false estimate that includes full credit rather than discouraged by one that does injustice. The numerical estimate of average success expressed as a percentage thus tends to become continually higher unless the generosity of the examiner is periodically and frequently checked by having his attention called to the absurdity of recording the majority of his students as distinguished. Dr. Ruffner says: "A temporizing professor who loves popularity, and desires, like the old man in the fable, to please everybody, is sure to be guilty of this fault, and, like many a politician, to sacrifice permanent good for temporary favor." If the passing mark is high, for example, 75 per cent., all marks will be proportionally high. What this limiting mark should be depends upon the idea underlying it. If the grade assigned means that the student is credited with knowing half, or three fourths, or nine tenths of what an ideally perfect student would know of the subject of study, the corresponding grade should obviously be 50, 75 or 90 per cent. Probably this is the most usual theoretic interpretation. But in practise the fundamental question is, in a large proportion of cases, not whether the student's attainments can be expressed accurately by a percentage, but merely whether in the teacher's judgment he ought to be passed or not. If so, his marks will be above the arbitrary limit, whatever may be the numerical value of this. If not, it makes little difference whether the grade assigned to the failure is 10, 30 or 50 per cent. In an institution where the teaching is good and where the discipline is firm and consistent, it is not often that more than one fourth of all students fail to pass in their studies. Theoretically, therefore, 25 per cent. would be better than 75 per cent. for the passing mark. This would mean no lowering of standard, but only a more rational system of marking than that which is most common. If results be represented graphically, the curve showing variation in grades attained would have its maximum corresponding to 50 per cent. This is an arithmetical mean between perfection and total failure, and should therefore be the numerical representation of the average grade. The curve would thus be substantially the symmetrical 'probability curve,' which is divided into two equal parts by the maximum ordinate, as shown in the accompanying diagram.

This study of the distribution of students' grades is worth more than passing notice, because it affords the best means of showing the tendency in relation to distinctions generally. Many years ago in a western university, by comparison of the grades of 287 students in physics, it was found that the average grade attained was about 85 per cent. In the institution with which the present writer is con-

nected, he made an investigation two years ago which showed that, taking into consideration all subjects of study available for the degree of bachelor of arts, the average grade of the average student under the average professor was 86 per cent., and that the most usual certificate conferred for successful work was a so-called 'certificate of distinction.' The curve of distribution is shown in contrast with the probability curve. According to this investigation it may be expected that about one student out of 200 or more will attain maximum grade. Out of 100 students about 10 may be expected to attain a grade of 95; 21



THE PROBABILITY CURVE HAS ITS MAXIMUM AT 50 PER CENT.; THAT OF DISTRIBUTION OF STUDENTS' GRADES AT 86 PER CENT. THE AXIS OF NUMBER OF STUDENTS IS VERTICAL; THAT OF PERCENTAGE GRADES IS HORIZONTAL.

will attain 90; 22 will attain 85. The slope of this unsymmetrical curve is thus very steep at the right. At the left of the maximum ordinate the slope is much more gentle, less than one twentieth of all grades assigned being below 60 per cent. In this connection it should be observed that the passing mark is 75. The area at the left of the dotted line corresponding to 75 is seen to be about one fifth of the whole area enclosed by the curve. This shows twenty per cent. of failures. Such a radical change of custom as that of substituting 20 or 25 for 75 as the passing mark, however desirable on account of its convenience and consistency, would be so misunderstood by both the students and the general public as to make a trial of the experiment very impolitic. The tendency to raise marks would at once re-assert itself, and very soon the majority of students would again be recorded with grades corresponding to the highest distinction.

This tendency to high marking is inherent in human nature. Every professor wishes to be at least as fair, at least as generous, as his conscience may permit; and he is apt to regard his own teaching at least as good as that of his colleagues. Every student wishes credit for the best he has done, and is at least willing to have his shortcomings excused. He considers the professor who gives him a high mark to be eminently fair; and the professor who remembers all shortcomings is thought to be unsympathetic and inconsiderate. To receive

a high mark is to receive a distinction, temporary perhaps, but none the less acceptable, and often stimulating, even if a high price has not been paid for it. All of us love to have others in sympathy with us, to receive expressions of esteem and to present testimonials of success. The supply becomes gradually adapted to the demand; and the demand causes all titles and distinctions to become more common, continually cheaper, until at last their meaning becomes merely nominal. To be nominally distinguished becomes the rule; to fail of such distinction becomes a disgrace.

In primitive society all government is the outcome of military organization. Aristocracy is originally based on brute force, and titles are the evidence of privilege accorded by the warrior chieftain in return for allegiance and military service. The assumption of a title without his consent is an act of rebellion and is treated as such by an absolute ruler. Limited monarchies have always been slow in development, and have in every case retained some features derived from the early establishment of caste fixed by privilege. The system of hereditary aristocracy which constitutes the groundwork of organization in English society is sustained by laws that could never have sprung originally from a democracy. Every Englishman knows his station. If he has not a place among the aristocracy by birth, he may still indulge the hope of admission to the charmed circle by royal favor. To call himself a lord, or to accept such a title by courtesy of his friends, or to buy it from some self-appointed college of heraldry would subject him at once to ridicule and social ostracism, even if he were not subject to prosecution for violation of long-established law. The mere fact of social organization imposes restraints upon personal liberty, but restraints that are deemed light in proportion to the general recognition of their reasonableness, justice and necessity. Personal liberty is, all in all, probably as nearly universal in England as it is in America, but the subjects in which limitation is imposed are somewhat different in the two countries. Titles and distinctions are granted in England in accordance with a well organized system, not theoretically perfect, but well enough established to be liable to but little misunderstanding. A colonel or a professor has no reason to fear ridicule in virtue of indiscriminate use of the title.

In America since the settlement at Jamestown there has been no basis for titles except the will of the more or less uninstructed people. Education was long exceedingly restricted. Aristocracy was based partly on personal character and partly on family influence, but never on legal prescription. There was no army requiring educated officers. A militia colonel was elected by his friends, and the title thus conferred by them was a possession for life. Throughout many parts of the south to-day by common consent a man is called colonel in virtue

of being a lawyer. No harm is intended by either the victim or the perpetrators of the practical joke. The explanation is perfectly simple, that by the inevitable process of good-natured degradation the words colonel and lawyer have in many places come to mean the same, neither of them suggesting the slightest suspicion of military education. In like manner, professors at first constituted a very limited class of scholarly men engaged in the work of college instruction, a class sharply differentiated from that of preparatory school teachers. This separation seems to have been maintained until the close of the civil war. But prior to the war the title had been assumed by dancing masters, showmen and all mountebanks. The good-natured American public, believing in universal freedom, had no objection to such thievery, and there was no law to prevent it. Annually the use of the title became more extended. Barbers, tailors, bootblacks and prize-fighters had as much right as the dancing master to assume any title that might have a commercial value. Teachers of high schools prepared students for advanced entrance in college. If the college teacher of geometry is called professor, why should not the distinction be extended to the high school teacher of the same subject? Moreover, what is the difference between a college and a high school? None whatever in many southern and western communities. If the high school teacher is a professor, why should a discrimination be made against the county superintendent, the grammar school principal, the primary school principal? The accommodating spirit of degradation has so changed the original signification of the word that now it may still mean a college teacher, but much more generally it means teacher without reference to the grade of teaching implied. Moreover, the great majority of teachers are persons with exceedingly small incomes; so that the title professor is in the large cities generally recognized as a badge of poverty.

Has the professor then no refuge from the charge of mediocrity implied in his once honored title? There is a Latin word for teacher, which was given a few centuries ago by the European universities to men who had proved their distinguished ability, such as Martin Luther or Nicholas Copernicus. The doctor was a man of learning, fit to teach medicine, or jurisprudence, or theology, or philosophy. Ambitious young men coveted the title, and the universities were places where doctors could lecture, and young men could enter upon the work of original investigation so as to establish their theses against all opponents. Even now the flood of literature made up of young doctors' theses in Germany is so great that no single reader can give attention to a tenth part of them. In America the university standards, in respect to both scholarship and scale of equipment, have risen so rapidly during the last few decades, that young doctors of all kinds are annually put forth by the hundred. The young man who is not a doctor

has now but little hope of winning the position of college teacher. The professor's refuge, therefore, is found in his doctorate.

But in this free country, made up of forty-five separate states with varying grades of civilization, each with its legislature able and willing to incorporate colleges with standards suited to local demands and local ideals, or absence of ideals, there is little hope of outgrowing the tendency to degradation of titles. If the dancing master was professor a third of a century ago, he is equally free in the early future to advertise himself as D.D., which for him means Doctor of Dancing. Our only hope is in the gradual elevation of educational standards, causing the people to become intolerant of such dishonesty. Titles received from universities should be protected by law in America as they are in Europe. The corrupt purchase and sale of professional degrees and of honorary degrees, which is now practised secretly, is to some extent punishable by law, but there is little vigilance in ferreting out offenders, and we seldom hear of prosecutions. Charlatanry will continue to be practised so long as there are gulls to be fooled in this world. Legislatures will continue to incorporate colleges without endowment, and these colleges will give degrees that imply no scholarship. With full knowledge that present evils will not be removed during the lifetime of any one now living, each educational institution that has a faculty of honest men can do its share toward the attainment of a higher moral standard of titles and distinctions by setting an example of truthfulness and moderation.

THE BIRD ROOKERIES ON THE ISLAND OF LAYSAN.*

BY PROFESSOR C. C. NUTTING,

STATE UNIVERSITY OF IOWA.

PERHAPS the most interesting experience enjoyed by the naturalists of the U. S. S. *Albatross* during her recent Hawaiian cruise was a visit to Laysan, an island situated almost in mid Pacific, about eight hundred miles to the west and a little to the north of Honolulu.

As viewed from the anchorage, a more uninteresting bit of land could hardly be found, there being nothing in view save a stretch of coral sand beach surmounted by low bushes and relieved by a wooden light-house and the sheds of the guano company that leases the island. On the morning of our arrival the surf was the worst seen during the entire cruise. Nowhere did there appear to be a spot where the heavy swell did not break in thundering roars, and the rollers appeared to be at least twenty feet high. One of our party succeeded in making a landing in a small boat manned by Japanese, and thus secured a day with the camera ashore on the far-famed island of Laysan, and the experience was one not soon to be forgotten.

FIG. 1. LIKE GREAT BROWN GOSLINGS, balanced on their heels, with their toes in the air.

The road to the main albatross rookery is of the same white coral sand that covers almost the whole island. The glare is exceedingly trying to the eyes, and the heat would be oppressive to one who found time to think of it. Birds are everywhere, and so tame that they actually have to be shoved aside with the foot. The road was dotted with the young of the white albatross, with a sprinkling of adults. The youngsters were but three months old, although fully as large

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as the adults, covered with brownish down, except on the breast where the white permanent feathering had in most cases been acquired. Their appearance is ludicrous beyond description, reminding one of great brown goslings sitting upright, balanced on their heels with their toes in the air. Upon being approached they make no attempt whatever to escape, but straighten up as if about to give a military salute and snap their mandibles together with great rapidity, making a rattling noise amusing at first, but annoying after a few thousand repetitions. Occasionally they resented the intruding foot and vomited a quantity of half-digested food, a most disgusting mess, over the trouser leg of the visitor.

FIG. 2. ACRES AND ACRES OF LEVEL GROUND LITERALLY COVERED WITH ALBATROSSES.

The scene at the main rookery is beyond description. Here are acres and acres of level ground worn bare of vegetation and literally covered with albatrosses. At the time of our visit probably four out of five were young birds born the preceding February, although adults are everywhere sprinkled among them. Although the vast majority are of the white species, there are a few sooty albatrosses which generally prefer the upper levels of the beaches. Of course all these youngsters have to be fed, and at any given time most of the adults are at sea fishing for sustenance for their rapidly growing and voracious progeny. So far as we could ascertain this food consisted almost exclusively of *squid*. The stomachs we dissected contained squid and nothing else, and the only solid excrement was the eyes and beaks of these animals. Mr. Schlemmer, manager for the guano company, estimates that about two million albatrosses make their home

on Laysan, and one can well believe it. Although aggregated most densely at the rookery, these birds are everywhere on the island, which is

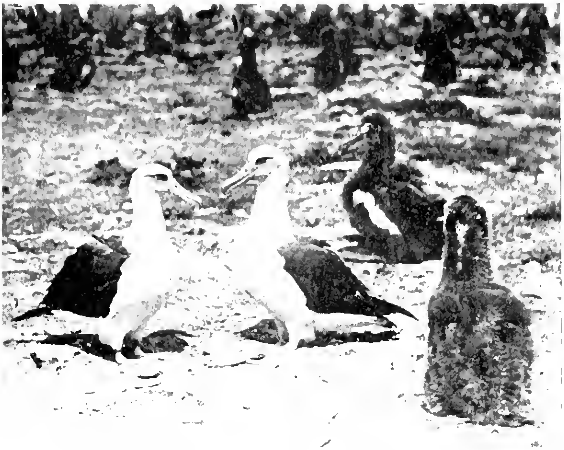


FIG. 3. ADULT BIRDS WERE EVERYWHERE SPRINKLED AMONG THEM.

in the shape of a rude quadrilateral about two by one and three fourths miles in area. Albatrosses are scattered everywhere, except on the tide-

FIG. 4. ABOUT TWO MILLION ALBATROSSES MAKE THEIR HOME ON LAYSAN. (From a photograph by Mr. Williams, of Honolulu.)

washed beaches and on the central lagoon. They are crouching under the shade of almost every bush and tuft of grass. The most conserva-

tive estimate of the necessary food supply yields almost incredible results. Cutting Mr. Schlemmer's estimate in two, there would be 1,000,000 birds, and allowing only half a pound a day for each, surely a minimum for these large, rapidly growing birds, they would consume no less than 250 tons daily.

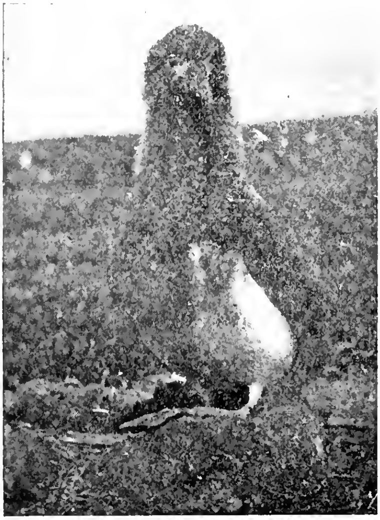


Fig. 5. Downy Young of White Albatross.

The young birds do not appear to move about much, otherwise the parents would have difficulty in locating them when bringing food, and one can not but wonder how each finds its particular progeny among the hundreds of thousands that appear exactly alike to the human eye. Both parents assist in the labor of feeding the young, a most interesting process. When the parent alights near the young bird the latter begins to beg energetically by gesture, for they are silent as a rule, crouching before the old bird and working the head backward and forward in urgent appeal. Then the youngster grasps the bill of the adult, holding it crosswise, but at an acute angle, when the partly macerated food is squirted with unerring aim right down the throat of the feeding bird, apparently without the loss of a drop. This process is repeated again and again until the parent has literally pumped itself dry.

Here and there are small groups of adults engaged in a sort of play that may be a continuation of the courtship antics, a most laughable performance. The birds commence by walking around each other in a sort of 'cake-walk' with a peculiar swagger suggestive of the 'bowery boy' in his glory. Then they snap their mandibles together with amazing rapidity, making a rattling resembling the drumming of the woodpecker. Again they stand upright, facing each other, and put their bills under their wings 'as if hunting for a cigar,' as suggested by one of our officers. Next they stretch their necks upward with bills pointed

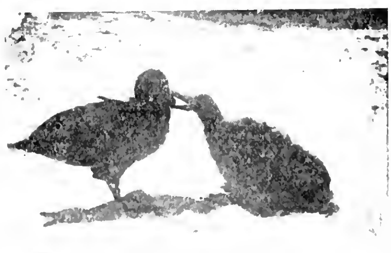


Fig. 6. Sooty Albatross Feeding Young.

heavenward, uttering a long-drawn 'ah-h-h-h-,' with a rising inflection. This play is repeated indefinitely, and with variations, and when, as

FIG. 7. HERE AND THERE ARE SMALL GROUPS OF ADULTS ENGAGED IN A SORT OF PLAY.

sometimes happens, it is accomplished in perfect unison, the effect is extremely laughable.

The life history of the albatrosses on Laysan, as given us by Mr. Schlemmer, is as follows: The eggs are laid late in January or early in

FIG. 8. THEY CIRCLE IN CLOUDS AROUND HIS HEAD.

February, both parents taking part in incubation. The nest is made by the female by merely scraping together the earth or mud wherever

she is resting and building it into an elevated ring within which her single egg is deposited. The young are hatched late in February,

FIG. 9. GROUP OF WIDE-AWAKE TERNS IN THE ROOKERY.

FIG. 10. THERE MUST BE MILLIONS OF WIDE-AWAKES NESTING AMONG THE BUSHES AND TUFTS OF GRASS.

usually, and both parents are kept busy from that time until fall in providing food for the little ones. By the latter part of September

the young have fully attained their adult plumage and are capable of sustained flight. Then the whole great host takes wing into the unknown. Literally so; for, so far as I can learn, this species, *Diomedea immutabilis* Roth, absolutely disappears from human ken for about two months of each year. There seems to be some evidence that it betakes itself to the Arctic seas. The apparent obliteration of this vast swarm of birds for a definite period annually is a mystery still to be solved. In November the birds arrive at Laysan as suddenly as they departed, and at once begin to prepare for domestic responsibilities. During the ten months annually spent there they do not appear to wander far from their breeding grounds. Indeed our vessel did not encounter them so far to the eastward as the main Hawaiian group.

FIG. 11. HOVERING WITH GRACEFUL POISE LIKE IMMENSE WHITE BUTTERFLIES.

Great as is the multitude of albatrosses and conspicuous as they are on account of their size, the terns of five or six species greatly exceed them in number, probably forming more than half of the entire bird population of the island. The clamor that greets the intruder in one of these immense tern rookeries is simply appalling, the air fairly quivering with their ear-splitting shrieks as they circle in clouds around his head and dash savagely directly at his face in their fierce endeavor to drive him away. There were probably hundreds of bushels of eggs of these birds at the time of our visit. The most numerous terns are the 'black-backed' and 'gray-backed' wideawakes, of which there must be millions, nesting among the bushes and tufts of grass, particularly on the southern end of the island. The vegetation grows right in the dazzling white coral sand, which appears as white as snow in the photographs.

FIG. 12. ROOKERY OF 'LOVE BIRDS.'

One of the most exquisitely beautiful birds that the writer has ever seen is a small tern known locally as the 'love bird,' pure white with large black eyes and bill. They have the habit of hovering with graceful poise over the intruder, like immense white butterflies, silently inspecting one as if impelled by a mild curiosity rather than resent-

ment, the actuating motive of the other terns. There are many small rookeries of these beautiful creatures scattered over the island; one in particular is in a very picturesque rocky nook at the south end.

FIG. 13. NODDY TERN ON NEST.

Two species of noddy terns are abundant, and much alike, except in size, being sooty brown with a grayish white cap.

FIG. 14. LARGE COLONIES OF MAN-O-WAR BIRDS WERE NESTING ON THE TOPS OF LOW BUSHES.

Large colonies of man-o-war birds were nesting on the tops of low bushes. These are among the most accomplished and graceful fliers

of all the avian world, and have the habit of soaring with extended wings for hours at a time. The males have an inflatable air-sack under the throat which can be distended at will into a great red pensile bag, resembling both in color and size the red toy balloons in which children delight. These birds are probably the most inveterate thieves and pirates of all the feathered tribe, robbing other birds of their fish, and even making them disgorge for the benefit of their persecutors. They lay a single white egg, and young in all stages of development were numerous. When the rookery was disturbed the incubating birds, both male and female, reluctantly left their eggs or young, in some instances carefully depositing a fish beside the young before leaving. Afterward, greatly to our surprise, they would swoop down, actually grazing our faces with their wings, and deftly seize a nestling by the head and make off with it, circling around high in air, finally dropping it to the ground, where it was eventually devoured. We could not

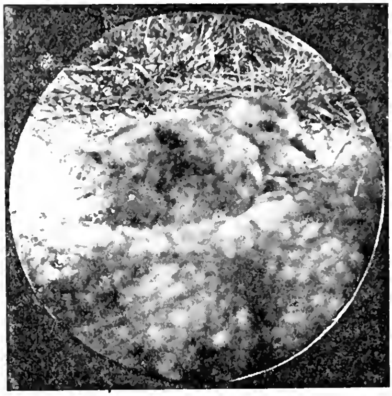


FIG. 15. YOUNG OF SHEARWATER SHOWING PROTECTIVE COLORATION.

FIG. 16. SHEARWATERS NEAR BURROW.

determine whether the parents actually destroyed their own young or not, but it is probable that this revolting form of cannibalism must be added to the other crimes charged to their account.

Fig. 17. Tropic Bird on Nest.

Not only does the bird fauna crowd all the available space on the ground, and in the bushes, and swarm in the air above, but still another vast multitude burrows under the sandy surface, forming a subterranean population that in itself would make the island of peculiar interest to the naturalist. Nor does the human visitor long remain in ignorance of this fact, for he has taken but a few steps anywhere among the bushes before he suddenly joins the 'submerged tenth' in a most undignified and precipitate manner, and is struggling waist deep in the yielding sand, an unwelcome invader of the home of the shearwater. This experience has the charm of novelty at first, but becomes exasperating after a score of repetitions in the course of an hour, with the perspiration streaming down one's face and the sand packed inside of one's shoes and clothing. How many scores or hundreds of thousands of these burrowing Procellaridæ there are on the island it is vain to estimate; but there are four or five species, and the entire surface is fairly undermined by their tunnels and burrowings. Their notes are melancholy beyond expression, being a distressful moaning, sometimes reminding one of the less romantic yowling of the night-wandering cat.

Fig. 18. 'Bush Gannet' on Nest.

Fig. 19. 'Sand Gannet' with Egg and Young.

As one walks among the bushes he is from time to time greeted with most strident and piercing screams from nesting tropic birds, rarely beautiful creatures, pure satiny white, the wings and tail mainly black, the two central tail

feathers being excessively elongated and bright red. When nesting these birds are so well concealed that they would be unnoticed were it not for their strident outcries. This resulted in distressful experiences when the 'jackies' from the *Albatross* were given shore leave, and went around pulling the tail feathers from every tropic bird they could find; the birds refusing to leave the nests, but protesting vigorously and occasionally getting revenge by biting savagely with their powerful beaks.

The gannets are among the more conspicuous birds of the island, being large white birds with black wings. They are known as 'bush

FIG. 20. WINGLESS RAIL (below); LAYSAN FINCH (to the left); LAYSAN HONEYEATER (to the right). From a group mounted by Mr. R. M. Anderson.

gannet' and 'sand gannet,' names indicative of their nesting habits. The downy young of these birds are exquisitely white and fluffy, reminding one of animated puff balls.

The Laysan duck, curlews, plover and turn-stones are found in numbers along the margin of the central lagoon, and furnish a welcome addition to the larder of Mr. Schlemmer and the men in his employ. Four species of land birds complete the list. One is the 'wingless rail,' not literally wingless, but with wings reduced to functionless rudiments.

Another species confined to this limited area is the Laysan finch,

a large sparrow with yellow head and under surface and a rich sprightly song; and the last is the 'Laysan honey-eater,' a minute form with body and head rich, dark red, abundant among some shrubs with red blossoms growing near the lagoon.

Of course any estimate of the bird population of this remarkable island is little better than guess-work, but it seems safe to say that at least six or eight million make their home on this small atoll in mid Pacific, the total area of which, including the lagoon, is only about three and one half square miles. I know of no more dense population anywhere, although it may possibly be matched on some of the islands in the Alaskan region. But there a vast majority of the birds leave during the winter, while at Laysan nearly all remain at least ten months of the year.

Much of interest could be said concerning the guano deposits and the operations of the company that leases the island. Thousands of tons are exported annually, and it is entirely possible that this valuable fertilizer is now being deposited as rapidly as ever it was, owing to the wise policy of not disturbing the birds that is rigidly enforced by the company. The excrement is almost entirely fluid, and gradually saturates and fills the thin soil and porous coral rock, thus making the 'guano' of commerce. Strangely enough there is no very perceptible odor, even at the rookery.

The naturalists of the *Albatross* spent a week in studying the fauna and flora of this exceedingly interesting island, while the naval officers made a complete map, including a chart of the reefs near the anchorage. Here are found unexcelled conditions for collecting and studying the life histories of birds. All the species are very abundant, and can be seen in a day's visit. Every species can be caught, either in the hand or with a hand-net, and mercifully killed with chloroform without mutilation or blood-stains. They can all be studied at leisure, and at close range. The photographer finds himself in a veritable paradise, able to set up his camera at any desirable distance, even to 'pose' his subjects to suit his fancy, and take pictures of birds, nests and young to his heart's content.

It is simply delightful to find one spot, at least, in this world of ours where the birds are not afraid. So long as the guano holds out, these conditions will probably remain unchanged. If this time comes to an end, the government should see to it that this wonderful preserve of avian life is protected from the ravages of man, the destroyer, and of the rapidly diminishing moiety of his better half that still persists in the aboriginal feather-wearing habit.

BACTERIA IN MODERN ECONOMIC AGRICULTURE.

BY ALBERT SCHNEIDER, M.D., PH.D.,

UNIVERSITY OF CALIFORNIA.

CROPS have been cultivated for thousands of years, and from the very first the agriculturist has endeavored to get from the soil a maximum return for a minimum of labor expended. Yet scientific progress in soil fertilization and crop improvement has been exceedingly slow until very recent years. Now scientific methods are beginning to be applied not only to crop and soil improvement, but also to the allied branches horticulture, arboriculture, the dairying industries, etc. That infant science, bacteriology, in particular, gives promise of inestimable value.

Some microorganisms work in the interests of the agriculturist, while others work decidedly antagonistically to all desirable interests. Much efficient work has been done in the eradication of disease-producing organisms, and the farmer is given detailed and specific instructions how to combat organisms which are hurtful to crops, as the rusts, smuts, rotting bacteria, etc. Attempts have been made to utilize even essentially harmful organisms in working useful results, as in the extermination of chintz bugs, potato beetles, plant lice; the extermination of rats, mice and other undesirable higher animals, by means of germs which are capable of transmitting fatal diseases to the animals referred to. The department of entomology at Washington has done some very effective work of this nature in exterminating insect pests of trees and plants.

The farmer's great future problem will be to determine what beneficial organisms may be pressed into his service and what noxious organisms may be suppressed, and how such measures may be carried out most expeditiously and with the best results. There is perhaps no problem of greater interest or none which gives promise of greater beneficial results than the one pertaining to the bacteria found in the root tubercles or nodules of leguminous plants (bean family). Without entering into the history of the discovery of these organisms or the part they play in the economy of the host plant, or even dwelling upon the many points still in dispute or under discussion, I shall describe briefly some of the recent attempts at making practical agricultural use of these organisms in Europe and in this country, and outline briefly a plan of future research, pointing out the additional practical possibilities which may be anticipated with reasonable certainty, based upon results already obtained.

It has been proved experimentally that not only do the bacteria (rhizobia) of leguminous root tubercles have the power of assimilating or chemically binding the free nitrogen of the air, but also other soil bacteria and various simple algæ and hyphal fungi. Undoubtedly the true ecological significance of these free nitrogen-assimilating functions of these organisms is to neutralize, balance or equalize the work of nitrifying and denitrifying (nitrogen-liberating) bacteria, which are very plentiful and widely distributed. More specifically considered, the organisms referred to chemically bind the free nitrogen of the air, forming nitrogenous compounds which may be taken up and assimilated by various plants. In the case of leguminous plants these nitrogen-assimilating bacteria (rhizobia) live within the roots (root tubercles) and supply the host directly with the enriching nitrogenous food compounds formed; in other instances the nitrogen-assimilating organisms live in the soil and the various higher plants as corn, wheat, etc., take up the compounds formed and deposited in the soil without being in actual biologic (symbiotic) association with them. These discoveries have suggested to the scientists interested in agriculture various possible improvements for increasing the yield of crops. Extensive and interesting experiments have already been made, and some noteworthy results have been obtained and, in other instances, investigations are under way which give promise of final useful results. Several processes for inoculating the soil or seeds with beneficial bacteria have been patented and, remarkable as it may seem, the slow, plodding German investigator is the first in the field with patent claims and 'practical' plans for utilizing bacteria in the interests of the farmer or the tiller of the soil.

The history of the discovery of the free-nitrogen-assimilating bacteria found in the root tubercles of leguminous plants is familiar to all botanists, but the general reader of science requires some detailed explanations and some specific statements regarding the subject in order that he may have reasonably clear ideas concerning the practical possibilities and probabilities of bacteria in modern agriculture. These necessary explanations will be given as we proceed.

The first to suggest a plan for practically utilizing root bacteria (rhizobia) and to secure letters patent for the process in Germany and in the United States were Nobbe and Hiltner, of Tharand, Germany. Since the wording of the specifications for a patent are required to be simple and intelligible to persons of ordinary technical learning, the scheme can best be presented by simply quoting the specifications. The following is the specification which forms part of letters patent No. 570,813 granted Nobbe and Hiltner in the United States, November 3, 1896:

Be it known that we, Friedrich Nobbe and Lorenz Hiltner, of Tharand, pared for transport in fluid cultures. The colonies in the agar-gelatin are dis-inoculation of soil for the cultivation of leguminous plants and we do hereby declare the following to be a clear and exact description of the invention:

Since the function of the root nodules or tubercles of the Leguminosæ in the supply of nitrogen to these plants has been discovered by the fundamental researches of Hellriegel we have been working on this problem for a number of years, and have examined more especially the bacteria in said nodules or tubercles (first identified and isolated in cultures by Beyerinck) in order to determine the relationship between the bacteria and the reception of the free uncombined nitrogen of the air in the soil by the various kinds of Leguminosæ. These researches have resulted, in the first place, in the confirmation of the at that time still disputed fact that the introduction of these bacteria into the soil produces, without exception, in soil free from these bacteria, the root nodules or tubercles on the plants in question having papilionaceous flowers and enables these plants to assimilate the free nitrogen. A soil inoculated with these bacteria, even when it contains absolutely no nitrogen in an assimilable form so that the plants without any such inoculation would starve, enables the Leguminosæ to produce as rich a yield of dry material and nitrogen as they would otherwise produce if grown in a richly manured soil containing much assimilable nitrogen.

It has been established by us as an entirely new fact that the tubercle bacteria of the various Papilionaceæ are of full strength (*i. e.*, in the production of efficient nodules or tubercles) only in that species (of leguminous plant) from whose root tubercles they were themselves obtained. With closely allied species they are of less strength and with systematically different species they are useless or inactive. Bacteria cultures from pea roots, for example, are quite useless for *Robinia* plants, while they promote the growth of peas in a very energetic manner, and that of the allied vetches somewhat more feebly; on the other hand, the bacteria from *Robinia* nodules or tubercles are quite efficient with *Robinia* plants, but in a lesser degree with *Colutea*, and are absolutely useless with peas.

At first sight it might possibly be thought that the production, transport, and distribution of such large masses of crude inoculating material as would appear to be necessary for the sufficient impregnation or treatment of large areas of land would be very difficult and costly, and therefore not practicable, while there would also be the danger that in the crude inoculating material, besides the active bacteria of the root nodules or tubercles, there would be carried from field to field, at the same time, microscopic organisms which would be detrimental to growth and would interfere more or less with the action of the inoculating material. Our process is, however, free from any such objections as those above mentioned, inasmuch as bacteria bred in quantities directly from the nodules or tubercles of the Leguminosæ in pure cultures are used as the inoculating material. Farmers are, therefore, placed in a position to make land, which was unfruitful by reason of its lack of nitrogen, fit for the cultivation of fodder and other plants belonging to the order of the Leguminosæ and to insure and increase the yield of soil. This inoculation has, moreover, an essential practical bearing in connection with the so-called 'green manuring.'

Our process of inoculating land with tubercle bacteria is to be carried out as follows: The active bacteria to promote the growth of the Leguminosæ are delivered to the farmer in glass tubes or other suitable packages, which contain pure colonies thereof in agar-gelatin having suitable additions for propagating such bacteria, for instance sugar, asparagin and an aqueous extract of the green

substance of the Leguminosæ. In some cases the bacteria can also be prepared for transport in fluid cultures. The colonies in the agar-gelatin are distributed in water, together with the agar-gelatin, by the user (after removing the stopper) in the proportion, for example, of the contents of one glass tube to from one to three liters of water, which is previously mixed with a suitable material, such as an aqueous extract of the green substance of Leguminosæ sugar asparagin, for propagating the bacteria. This propagating material is delivered with the bacteria tubes. Preferably the glass tube is laid in the water until the agar-gelatine is dissolved.

Immediately before sowing, the whole of the emulsion prepared as above mentioned is poured over the seeds. The amount of water added for each kind of seed is so proportioned that after the seeds have been thoroughly and uniformly moistened by a careful working over by hand, a surplus of liquid will still remain. For clover-seed, for example, for twenty kilograms of seed the admixture of three liters of water with the contents of three glasses of inoculating material (each glass containing, for instance, three cubic centimeters agar-gelatin with pure cultures) is sufficient. For more bulky seeds a somewhat larger amount of water is required. A sufficient quantity of dry sand or earth from the field to be sown is then gradually added with careful stirring, until the body of seed is in a suitable condition for sowing by hand or by means of a sowing machine.

This microbic (rhizobic) soil fertilizer for leguminous plants was given the commercial name 'nitragin,' and its efficiency was quite carefully and extensively tested and commented upon by European and American investigators. The consensus of opinion seemed to be that it was of doubtful practical utility for agricultural purposes. Some authorities maintained that it was of unquestionable value in virgin soil. In rich and otherwise favorable soil conditions it is of only slight value. It is maintained that nitragin aids very materially in developing and ripening the fruit. As becomes evident from careful consideration, the value of this microbic fertilizer depends upon whether it will cause an increased development in the number and size of root tubercles over and above those which would develop without the presence of this artificial aid. If the soil is already well supplied with rhizobia or root tubercle bacteria, as soil naturally would be if the leguminous plants under consideration had been grown in it for one or more seasons, nitragin would in all probability be of little or no value. In any case the anticipated practical results have not been realized, as I am informed by a letter from Victor Koechl & Co. of New York City which states that 'nitragin is withdrawn from the market and is no longer manufactured.'

A second and later improvement in the method of inoculating seeds with root tubercle bacteria (rhizobia) is given by Hartleb in the following specifications forming part of letters patent No. 674,765, granted May 21, 1901, at Washington, D. C.:

Be it known that I, Richard Hartleb, a citizen of Germany, residing at the Botanisches Institute der Hochschule, Aachen, in the Empire of Germany, have

invented a certain new and useful method of inoculating seeds with micro-organisms, (for which I have applied for a patent in Germany, dated February 23, 1900) of which the following is a specification:

This invention relates to a method of inoculating seeds with microorganisms. For this purpose the seeds in a suitable container are covered with pure water, so that they are mechanically cleaned, and the damaged or dead seeds float to the surface of the water. The water and the impurities are then poured off and the cleaned seeds are left in the water until they begin to swell. whereupon there is a loosening of the external husk of the seed and an increase in the volume of the grain, so that the seed offers an increased surface for the microorganisms and the latter obtain easy access, owing to the loosening of the husk. The seed thus prepared is sown directly without admixture of any other substance.

The application of this method is to the inoculation of seeds with bakteroids of the microorganisms of the Leguminosæ. Very shortly after the seed has become imbedded in the soil nodule (root tubercle) formation begins. The danger of killing the organisms for the inoculation by harmful soil influences is effectively obviated, owing to the fact that these organisms in consequence of the rapid germination quickly become active. On the other hand, this danger of damage or death is always present in a seed which has been merely inoculated with the liquid and has not been allowed to swell therein, so that it is a long time in germinating.

Although not specifically stated in the above specification, it is evident that the Hartleb process is a method of applying pure rhizobia cultures to seeds of leguminous plants only. Whether the method offers any advantages over the method of Nobbe and Hiltner is questionable. In any case it would prove practically advantageous only under the conditions referred to under the discussion of nitragin. Although the method has been freely discussed and experimented upon in Germany, I am not aware that the fertilizer is on the market, certainly not in the United States.

There is on the market a third patented germ or microbic soil fertilizer of German origin known as 'alinit.' It consists essentially of a pure culture of the soil bacillus known as *Bacillus Ellenbachiensis alpha* or *Bacillus Ellenbachiensis* Caron. The germ was first brought to the attention of agriculturists by Caron, a land owner of Germany, who first isolated it and called attention to the fact that it had the power of chemically binding the free nitrogen of the air. The microbe is undoubtedly closely related to *B. megatherium* and perhaps also to *B. anthracis*. According to some authorities it is especially concerned in assimilating free nitrogen for gramineous plants (grass family, *Gramineæ*). If this is true it may prove of great value to grain growers.

The commercial alinit is a dry pulverulent substance of a yellowish gray color, with about 10 per cent. moisture and 2.5 per cent. nitrogen. It is evidently prepared by mixing spore-bearing pure cultures of the bacillus of Caron with a base of starch and albumen. It

is used to inoculate soil either by spreading it broadcast or by sowing or otherwise planting it with the seeds. It is not a nodule or root tubercle-forming organism and does not enter into intimate symbiotic or biologic relationship with plants. Its work is simply that of binding free nitrogen, forming nitrogenous compounds which enrich the soil, thus increasing the yield of any crop benefited by such compounds. Whether alinit binds free nitrogen more actively in the presence of gramineous plants must be more accurately determined by experiment.

In 1892, through a suggestion by Professor Conway MacMillan, state botanist of Minnesota, the writer conceived the idea of modifying leguminous tubercle bacteria by special culture methods so as to induce them to develop in or upon the roots of gramineous plants, as corn, wheat, oats, rye, and barley. Investigations in this direction were begun at the Illinois Experiment Station at Champaign in 1893, under the direction of Dr. T. J. Burrill. The time granted for experimenting was much too brief for obtaining any definite results. At that time comparatively little was known of nodule bacteria (rhizobia) in artificial culture media and most of the time allotted was consumed in making cultures or attempting to make cultures of the rhizobia of different species of leguminous plants. No field experiments were attempted, but some laboratory observations were made by inoculating sprouting corn grown in vessels filled with sterile sandy soil with pure cultures of rhizobia grown upon corn extract agar media, the supposition being that the corn extract would produce the desirable changes in the organisms. After a few weeks the roots of the young inoculated corn plants were examined microscopically to determine if the presumably modified microbes showed any tendency to develop in or on the root cells. In some instances numerous microbes were found in the hair cells (trichomes) of terminal rootlets and in epidermal cells and cells in apical areas, particularly at the points of secondary root formation. While it was not experimentally proved that the microbes present were rhizobia, it is highly probable that they were, as the examination of control plants not inoculated, also grown in sterile sandy soil, showed the absence of germs in root tissues and root trichomes. It was apparent that the inoculated corn plants were thriftier and of a deeper green than the control plants or those not inoculated. Though the results are meager and far from conclusive, yet the experiments pointed toward final, more positive results. The experiment station research was now terminated, and other work kept the writer from again taking up this line of research extensively until early in 1902. At this time the investigations were begun in the bacteriological laboratory of the Northwestern University School of Pharmacy at Chicago. Pure cultures of the rhizobia of white clover

(*Melilotus alba*) were grown upon corn extract with agar. Again considerable difficulty was encountered because of lack of information regarding the behavior of this particular variety or species of rhizobium in artificial culture media. It was not until the early part of July that definite and satisfactory conclusions were reached regarding the identity of this organism in the culture media indicated. The rhizobia were now transferred to fresh corn extract media from time to time for about six weeks; in order to effect the desired adaptive changes in the microbes. Some preliminary field experiments were carried on at a farm near Fairbury, Illinois. Plots of stubble ground were selected in which oats had been grown during the season. The ground was ploughed and harrowed repeatedly. Each plot of ground was duplicated for control purposes. On August 10 the plots were planted with white dent corn mixed with the rhizobia cultures and a small quantity of water. The seeds germinated uniformly with no appreciable differences in the various plots. Subsequent growth was carefully observed for a period of four weeks. No very marked difference was noticeable. The corn treated with rhizobia grown in neutral corn-extract agar seemed to thrive somewhat better than the rest, but the difference was not sufficiently marked to be noteworthy. The corn treated with acid agar corn-extract rhizobia showed no apparent improvement over the normal or untreated corn. The same could be said of the corn treated with crushed nodules of sweet clover. Opportunity did not present itself for making a comparative microscopic examination of the roots of the corn of the various plots. Oats was also experimented upon, but with no marked results. This in brief is the outline of the experiments of 1902 and, although no satisfactory results were obtained, the preponderance of experimental evidences again seemed to point to ultimate success. In fact so sanguine had the writer become of early marked success that he made application for letters patent for the process, but the application in the form in which it was presented was rejected on the patents by Nobbe and Hiltner and by Hartleb. The specifications filed September 29, 1902, read in part as follows:

> The invention relates to the process of fertilizing the soil and increasing the yield of crops by means of specially modified pure cultures of the microbes or organisms found in the soil and in the root nodules or tubercles of plants belonging to the leguminosæ or bean family, and has for its object to render the process more effective, much cheaper and practically without the expenditure of additional labor.
>
> The living microbic fertilizer, consisting of the above mentioned modified organisms is applied by simply mixing a small quantity of the culture with the seeds just prior to planting, and introducing it into the soil simultaneously with the seed. With the germination of the seed thus treated, the modified microbes will also begin to multiply and appropriate for the use of the plant, the free nitrogen of the air.

In spite of the wonderful opportunities for the dissemination of learning, the exchange of scientific thought and plans of research and the efficient modern laboratory equipment, scientific progress is slow. To illustrate, the observations and experiments which led to the discovery of the root nodule bacteria were begun about 1862 by Hellriegel in Germany and Lawes and Gilbert in England. The nodule microbe was not discovered or recognized until 1886. At the present time we are just beginning to become scientifically familiar with the microbe and are undertaking experiments with a view to practical useful application of this microbe. In consideration of these facts it need not appear surprising that conclusive results should not, at the time, have been obtained in the line of research indicated. It is of course understood that any scientific research deserving of the name must be founded upon reasonable and sound principles. The entire experimental plan must be in harmony with the highest and best results already obtained. The following are the essential and important points for consideration and upon which the research work indicated is to be based:

1. Do rhizobia (nodule bacteria of leguminous plants) assimilate free nitrogen in artificial culture media or when not symbiotically associated with leguminous plants? Based upon the results of extensive research work, in particular by German investigators, this question is to be answered in the affirmative. A negative result would mean that it would in all probability be wholly impossible to obtain the anticipated outcome of the experiments. Since this question is, however, to be answered in the affirmative, the next question in importance is

2. Can rhizobia of leguminous plants be so modified by special culture methods as to induce them to develop in and upon the roots of other plants, as corn, wheat, rye, barley, etc.? Although, as already indicated, the experimental results thus far obtained are not conclusive, yet the *indications* are that they will finally prove successful. German investigators have shown that one variety of leguminous rhizobium may, by culture methods, be converted into another variety. That is, for example, the rhizobium of the bean nodules may be induced to develop nodules on the roots of the pea, and perhaps other species of closely related genera. This is, in part, denied by Nobbe and Hiltner in the specifications of patent claim, as above recorded. It is, however, generally admitted by investigators that the rhizobia of the majority of leguminous plants are morphologically very variable, and undergo very marked structural changes in different culture media and within the host root nodules at different periods of the season and of growth. Such pronounced polymorphism coincides with marked adaptive changes to new or changed environment, and it is, there-

fore, highly probable that these polymorphic rhizobia may be induced to change hosts, at least temporarily, which is really all that is required for the success of the experiments. That is, it is desired that the rhizobia should live and multiply in or upon the roots of gramineous plants during one season or from the time of seed germination to the ripening of the crop (in annuals). This question is intimately associated with the following:

3. Even should it be possible to induce the rhizobia to develop in and upon roots of gramineous (and other non-leguminous) plants, would they still retain the power of assimilating free nitrogen? It is highly probable that this question can be answered in the affirmative, although Lafar makes the statement that the rhizobia in certain stages of existence, for instance those which exist in the infecting threads (Infectionsfäden) of nodules and predominate in young tubercles and in the apical areas of all tubercles, exist in a purely parasitic or harmful relationship with the host plant. It is, however, highly probable that this statement is not founded upon experimental proof. The assimilation of free nitrogen is an essential function of rhizobia, and it is certainly reasonable to assume that the function would continue, though perhaps in a modified degree, no matter how marked the morphological adaptive changes might be. This question can be settled very simply and easily as the experiments progress.

The following question should also be carefully considered:

4. Are there soil bacteria or other organisms, not found in leguminous root nodules, which assimilate free nitrogen and which may be especially adapted to gramineous plants? From what has already been stated, it would appear that the *Bacillus Ellenbachiensis* of Caron is such an organism. If it should become evident that this organism assimilates free nitrogen principally in association with gramineous plants, it would seem to give promise of great utility in the more effective cultivation of gramineous plants. This organism would be especially advantageous, because, in contradistinction to rhizobia, it forms spores. Spore-bearing cultures would be desirable, because they would keep better and longer. The microbic fertilizer could be put up in dried form and sent to farmers at great distances without danger of becoming worthless. It could be kept for months, or perhaps even a year or more, though this in itself would not be of prime advantage. Further extensive researches would be necessary to determine to what extent adaptive changes could be developed in this particular microbe.

Finally the question will arise,

5. In what morphological, biological and bio-chemical relationship would the modified organisms establish themselves with the prospective or new host plant? It is, of course, not to be anticipated that they would cause the development of root nodules or tubercles or cause

any considerable morphological change in root tissues. Nor is it at all highly probable that the anticipated morphological and biological adaptive relationship would be permanent or auto-transmissible to other generations of the new host. It is probable that the relationship would be temporary only. It may be quite marked at the period of seed germination and then gradually decline more or less rapidly.

The time required to change or modify the rhizobia sufficiently to induce them to develop in or upon the roots of gramineous and other non-leguminous plants must be determined experimentally, and this is the most essential part of the experimentation. It is reasonable to assume that considerable time will be required, one year, and perhaps even a much longer period. It will also be necessary to experiment with various media in order to determine which particular culture medium will produce the desired changes most effectively and most rapidly. Present indications are that acid media are not specially indicated as was once supposed, though they induce rapid and very marked morphological changes in the rhizobia.

The agricultural conditions of Europe are quite different from those of the United States. In the plan of research suggested, the interests of the American farmer are of prime importance. Wheat and corn are the two staple farm products of the central, eastern and western states, and in the above discussion these have been primarily in mind. Later researches may be extended to other American farm products, as cotton, tobacco, potatoes, etc. Opportunity must be had to make frequent field experiments or tests along with the purely laboratory experimentation.

The successful outcome of the research will result in inestimable value to farmers. The modified microbic soil fertilizer will serve essentially as a living fertilizer; it will do away with the use of the well-known guano, manure and other chemical fertilizers, which are applied at great labor and expense. It will also do away with the need of crop rotation, which to the agriculturist is a costly process, as it necessarily reduces the cultivation of the staple farm product. It is hoped that the increase in crop yield, resulting from the use of the microbic soil fertilizer, will amount to from 5 per cent. to even 50 per cent., depending primarily upon the condition of the soil. Rich soil naturally requires no fertilizer of any kind.

The following is a brief summary of the essential points discussed in this paper with special reference to the plan of research outline:

1. Bacteria of the root nodules of leguminous plants (rhizobia) have the power of assimilating free nitrogen independent of their intimate biologic association with the host plant.

2. Rhizobia, especially the species known as *R. mutabile,* found in the root nodules of the majority of leguminous plants, are highly poly-

morphic and readily undergo marked morphological changes in different culture media and under varying environmental conditions.

3. The species or variety of rhizobium living in natural symbiotic or biologic relationship with one given species of leguminous plant may be so modified artificially as to induce it to live in a similar relationship with a different species of leguminous plant, indicating great biologic adaptability.

4. It is probable that rhizobia of various leguminous plants may be so modified by special culture methods as to induce them to develop in or upon the roots of non-leguminous plants, continuing their free nitrogen-assimilating function, thus supplying such plants with nitrogenous compounds which serve as soil fertilizer or food for the plants with which the modified rhizobia will form a temporary intimate relationship.

5. The bacillus of Caron (*Bacillus Ellenbachiensis*) also gives promise of great utility in future economic agriculture, especially in the cultivation of gramineous plants.

THE STORY OF ENGLISH EDUCATION. II.

By J. E. G. DE MONTMORENCY, B.A., LL.B. (Cantab.),

BARRISTER-AT-LAW.

IT is not possible in the space allotted to such an article as this to deal in any detail with the mass of facts that fill the seventy years that have passed since this first government grant in aid of education. It is possible, however, to indicate the course of events. Previous to 1870, apart from unsatisfactory and more or less ineffective factory acts, and apart from revenue statutes providing yearly grants, there was no legislation. Educational work was undertaken for the most part by the education committee of the Privy Council, formed in 1839, and the great school societies. From 1833 to 1839 the annual grant of £20,000 was administered by the treasury through these societies. In 1839 Queen Victoria, on the occasion of the creation of the committee of council on education, expressed through Lord John Russell the wish 'that the youth of this kingdom should be religiously brought up, and that the rights of conscience should be respected.' Some statistics of a comparative character may here be noted with advantage. The population of England and Wales in 1833 was almost 14,000,000, and the number of day scholars of all classes nearly 1,300,000, a number that was about nine per cent. of the population. If one in every eleven of the population was at school, it did not prove that the working classes were in so favorable a case. In fact we may take it that under one million scholars belonged to the working class; in other words that not one in fourteen of the laboring population was at school, when in fact, one in six ought to have been at school. Thus a great many more than half of the children had no education at all. By the year 1851 matters had somewhat improved. The population was then about 18,000,000, and of this population some 1,600,000 of the children of the laboring poor were at school. In other words, about one in ten instead of one in six of the poorer part of the population were at school in 1851. At this date almost exactly half the children had no education at all. By the year 1870 the population had reached 22,000,000, of whom 19,000,000 constituted the manual-work class. About 1,700,000 children belonging to this class were at school, or say, one in eleven of the population. This looks like a decline on the position in 1851. This is, however, extremely improbable, and it is more likely that the available figures for 1851 are in error. The improvement between 1851 and 1870 was most marked in the methods of education employed and in the books used. The school-teaching was practically valueless in 1833, it was not of great value in 1851, and

in 1870 it was only beginning (despite the great advance on 1851) to be of real value. In 1870, out of every 1,000 children qualified by age and attendance for the examination in the two higher standards, 319 ought to have been prepared to pass. In fact only 98 were presented for the examination. Slow as was the progress between 1833 and 1870, ceaseless efforts had been made to hasten that progress. Population and the congestion of soul-ruining unsanitary areas, however, progressed more rapidly than the education movement and 1870 found a million and a half of little children without the means of education. Yet philanthropists and statesmen had striven manfully enough to solve the awful problem. A select committee of the House of Commons in 1838 reported on the deplorable conditions of education in the great towns. This led to the institution of the education committee of the Privy Council. The inquiry made by the National Society in 1846–7 showed that the established church was striving with might and main to do its duty, for it was actually educating one million children in its day schools. A select committee of the House of Commons in 1852 reported on the Manchester district of England and showed a school attendance improvement of no less than 300 per cent. The Duke of Newcastle's commission appointed in 1858 recommended, after a lengthy examination of the education problem, grants out of rates as well as out of the imperial exchequer, advised the creation of local boards of education in every county area, advocated a more efficient system for the training of teachers, and an extension of evening schools. The grants out of the rates were to be paid in respect of individual scholars upon examination by examiners appointed by the local boards of education. The revised code introduced by Mr. Lowe—the code governing the conditions under which the education committee of the Privy Council made the grants to the schools—adopted the principle of individual examination and the payment of all grants direct to the managers of the schools that earned the grant. Mr. Lowe in a famous phrase promised that the system should be either cheap or efficient. When he made this promise it was dear and inefficient. Under the revised code the parliamentary annual grant fell from £813,441 in 1861 to £636,810 in 1865. The system, however, was not efficient and it was found necessary once more to strive after educational legislation. In 1843 an effort had been made to pass a factory act that would secure some measure of religious and useful education to all children in the factories. The bill, however, in consequence of nonconformist opposition, was withdrawn. In 1853 a bill was introduced enabling those borough councils that chose to adopt the act to appoint a school committee for the purpose of controlling the elementary education of the district. It was proposed in this measure that any elementary school should be admitted to this control and reap its manifold benefits on the application of the school

managers for such admission. Admitted schools were to be inspected. Expenditure under the act was to be met out of the borough fund to the extent of sixpence on the pound. The bill was coldly received and withdrawn. About the same time were introduced education bills emanating from Manchester school societies. One advocated free secular rate-paid education; the other the assistance out of the rates of denominational schools. These two bills were referred to a select committee of the House of Commons on February 17, 1853. The bills were eventually dropped. In 1855 the denominational bill with a provision for the foundation of new schools was re-introduced by Sir John Pakington. In the same session Lord John Russell introduced another borough bill, with a full conscience clause; while the free schools bill again represented the views of the Manchester secular party. The three bills were all abandoned. Bills were once more, without effect, introduced by Lord John Russell in 1856 and Sir John Pakington in 1857. These were followed by the comparative unsuccess of Mr. Robert Lowe's revised code. In 1867 came the beginning of the end, or rather of the beginning. What was practically the Manchester denominational schools bill was introduced by Mr. Bruce, Mr. W. E. Forster and Mr. Algernon Egerton. It was a carefully prepared scheme, but unfortunately it was not compulsory in form. Each locality could adopt or refuse it. In the then state of education the worst districts would have refused to adopt the act. The bill was withdrawn, and in 1868 the Duke of Marlborough introduced into the House of Lords a bill that purported to solve the problem without the aid of rates. The bill merely proposed to put a modification of Mr. Lowe's administrative code into an act of Parliament. Such a bill could but fail. In the same year the bill of 1867 was again introduced, and on this occasion it offered the compulsory system. The feeling that this bill would involve compulsory rate-aid for denominational schools under private management, and the fact that it gave the proposed board of education power to enforce the act in any district exhibiting educational destitution, contrary to the will of the district, weighed against the bill and it was withdrawn on June 24, 1868. The final step came when the bill of 1870 was introduced on February 17. It received the Royal consent on August 9, 1870.

The education act of 1870 divided England into school districts for the purposes of elementary education, and enacted that in every district a sufficient amount of accommodation must be provided in public elementary schools for all children resident in the district, for whose elementary education sufficient and suitable provision was not otherwise made. The meaning of 'elementary education' was not defined by the act, but in the famous *Cockerton case*, decided in 1901, it was settled that the phrase was an elastic term 'which may shift with the growth of general instruction and

attainment.' The schools were bound by a conscience clause and had to be open to government inspectors, who could report whether the conditions laid down by the central authority as precedent to a grant had been complied with. This new system comprised two kinds of schools—the schools supported by voluntary subscriptions, which were in existence at the date of the passing of the act, and board schools. These latter schools came into existence in districts where there was insufficient voluntary school accommodation and where in consequence the rate payers had elected a school board. This board erected, at the expense of the rate payers, schools sufficient to supply the wants of the district, and these schools were maintained out of the rates, central grants and school fees. In the board schools, in addition to the conscience clause in use in voluntary schools, the Cowper-Temple clause of the act of 1870 enforced the rule that 'no religious catechism or religious formulary which is distinctive of any particular denomination shall be taught in the school.' Thus the effect of the act of 1870 was to place side by side two great school systems—a denominational system, the schools of which had for the most part been built and were maintained by voluntary subscriptions, to some extent supplemented by grants—and an undenominational rate-supported system independent of voluntary subscriptions. The passage of years saw the rapid increase and development of both systems. The act of 1870 gave the various school boards power to compel parents by by-laws to send children to school between the ages of five and thirteen years, but it was not until 1876 that the legislature created the universal parental duty of causing all children to 'receive sufficient elementary instruction in reading, writing and arithmetic.' This was followed in 1891 by an act granting to practically all the public elementary schools a fee-grant in lieu of the fees hitherto paid by the parents. This important step of creating free elementary education was an almost necessary corollary of the institution of compulsory education, and it was essential for the reason that those children who most needed school life were the offspring of the most needy parents. The result of these various acts was to create vast school board systems in London and the great towns which in certain areas crushed the voluntary schools out of existence. The standard imposed by the Education Department rapidly rose, and the number of subjects taught greatly increased. Gradually the great school boards endeavored, by the creation of what were known as higher elementary schools, to bring secondary education within their control and to supply this education out of the rates in competition with the newly-efficient endowed secondary schools of their districts. In 1901, in the famous case of *Cockerton*, it was held that this was illegal, and it became necessary at once to create by statute a national system that should control and develop both primary and secondary education. The school board system, while it had been

successful in imparting in the great towns a considerable measure of elementary education to the mass of the poorer children, had had a bad influence in lowering the standard of secondary education by compelling the strictly secondary schools to come down to the standard of the higher elementary schools. Higher elementary education at its best gave the child some smattering of culture but it ended there and was in no sense a step in the ladder of education. In the rural and urban districts, moreover, the voluntary schools had more than held their own. The board schools of these districts were often badly managed and were less efficient in many cases than the voluntary denominational schools, which, despite financial difficulties, increased in number and efficiency. The fine work done by these schools was considered to justify in 1897 the creation of a special aid-grant to voluntary schools. But even with such help the position of the voluntary system had become precarious. The high standard of elementary education, of accommodation and of teachers imposed by the Board of Education could only with great difficulty be attained with the means at the disposal of the managers of voluntary schools. The subscribers increased their subscriptions, but since as rate payers these subscribers had frequently also to pay a school board for schools competing with their own schools, it was plain that the limit of subscriptions had been nearly reached. It was clearly inequitable that a person should pay to support both a voluntary and a compulsory system, and it was also evident that both systems suffered in efficiency in consequence.

The time, therefore, had been reached when all forms of education required coordination and increased state help. The absence of continuity between the various grades and kinds of education had, by the year 1902, become a serious national danger. I have noticed already some aspects of this discontinuity. It is necessary here to refer to certain other sides of the question. For nearly fifty years the Science and Art Department of South Kensington had distributed under the direction of the Education Department—now the Board of Education—to schools of all kinds a large parliamentary grant in aid of an elaborate scheme of education set forth by the South Kensington officials. The school boards for a considerable period used the rates, quite illegally, for the purpose of teaching science and art in accordance with the South Kensington scheme in order to earn the grants. This scheme provided the elementary schools with a kind of secondary system and thus increased an undesirable competition with the endowed secondary schools. On the other hand these true secondary schools from the year 1890 have received in many instances parliamentary help of another character. By an act of that year the residue of certain customs and excise duties—a very large annual sum*—was directed to be dis-

* Say £1,200,000. The Science and Art grants and these duties amount to more than £1,500,000, so that it can hardly be said that secondary education has, since 1890, been neglected in England.

tributed to the County Councils throughout the country for the purpose of encouraging technical education. This money was and is awarded to the secondary schools by way of grants in recognition of successful results achieved by the school in technical education. These grants have proved so necessary to the various secondary schools that such schools have been compelled to start an efficient system of technical education in order to earn them. In this respect competition with the primary schools has done good. It has forced the secondary schools to find a new source of income beyond endowment and fees and has thus brought the ancient secondary or grammar school system of England into relationship with the state. The state has not been slow to recognize the relationship. In addition to the technical education grants it now makes special grants to all secondary schools that are prepared to attain a certain standard of efficiency in certain subjects—scientific and literary—named by the Board of Education. It is not, however, difficult to see how confused and conflicting was the whole system. It was in fact gradually becoming impossible to differentiate between primary, higher elementary and secondary education. The *Cockerton case* at last, by restricting the board schools to strictly elementary education, made it necessary for the legislature to review the whole position. It was evident that the *Cockerton case* could not be allowed to lower the standard of national education; it was equally evident that a glorified school board system meant the ultimate ruin of all forms of tertiary or university education so far as the masses were concerned. These aspects of the problem were obvious to all who were not blinded by hatred to the established church into refusing aid to the voluntary schools, or who were not members of school boards and believers in the eternal fitness of a higher elementary *cul de sac* training.

In order to place national education upon a sound basis it was necessary that every possible grade of education from the infant classes of elementary schools to the post-graduate classes of the universities should form one continuous system, and that there should be no competitive overlapping between its various parts. It was also necessary that the system should in no way run contrary to the almost universal national belief that christian religious teaching in some form or another, denominational or undenominational, must take a definite place in the education of children. The Board of Education act, 1899, to some extent paved the way for the elaborate national system that is now, under the act of 1902, in a fair way to become effective. The act of 1899 established a board of education to take the place both of the education committee of the Privy Council (known as the Education Department) and the South Kensington Department of Science and Art. It gave to this new board the power to inspect all secondary

schools that desired to be inspected and gave to the county councils the power to pay for such inspection, thus bringing the councils into closer connection with the secondary system. The act also provided for the creation of a consultative committee (consisting as to two thirds of persons representing the views of universities and other bodies interested in education) for the purpose of framing a register of teachers throughout the country of all grades and for the general purpose of advising the Board of Education on technical educational matters. This committee is proving a most effective body, and it will soon be difficult for any school of repute to reject official inspection and for any schoolmaster of standing to withhold his name from the official register. The act also gave the Board of Education the capacity to take over and exercise any powers of the charity commissioners or of the board of agriculture relating to education. The vast powers exercised by the charity commissioners over the secondary endowed schools of the country under the endowed schools act of 1869 and the amending acts, were vested last August, by virtue of this provision, in the Board of Education. The result of this step was to make the Board of Education the supreme authority over both primary and secondary education and to bring it into touch with the county councils in relation to all secondary matters. The next obvious step was to replace the school boards by the county councils (and county borough councils) and thus make the local administrative authority an intermediary in the cases of *all* grades of education between the schools and the Board of Education. This is the great accomplishment, from the educational point of view, of the act of 1902. The school boards in their vain efforts to supply something of the nature of a secondary education were rapidly making confusion worse confounded. By the simple expedient of placing the local secondary authority—the county council—in the place of the school board, the principle of order and development was at once introduced into the national educational system. The supporters of the school boards—men who realized the admirable work that had been done by these boards, but who were unable to grasp the fact that that work could be more efficiently continued by bodies that had the interests of secondary as well as primary education at heart as part of a civic system—opposed the bill with fierce energy, and they were aided by all those who believed that the new bill was unduly helping the elementary denominational or voluntary schools. The government with respect to those schools was in a difficult position. The owners and managers of the schools claimed as of right assistance out of local rates on the ground that they were doing work which if they did not exist would have to be done by new schools built by a school board at great cost. They, however, refused to alter the denominational character of these schools. They declared that the con-

science clause, protecting the religious beliefs of children of other denominations attending the schools, was sufficient. The government had, therefore, the alternative of helping these voluntary schools on terms and thus knitting them forever into the national system, or of building at a cost of £120,000,000 schools to compete with these schools, or of buying them compulsorily at a cost of over £50,000,000 and starting them as undenominational schools. Obviously, the only businesslike course was to make terms with the voluntary schools. The bill was fought in the legislature for a period of nine months, but eventually passed, retaining the principles contended for by all economists and educationalists of weight in the country.

I must briefly note the provisions of the act. The first section enacts that every county council and county borough council and the borough council of every non-county borough with a population over 10,000 and the district council of every urban district with a population over 20,000 shall be the local educational authority for elementary education, while the county council and the county borough council are the authorities for higher education. In the case of *all* non-county boroughs and urban districts the borough or district council may supplement the work of the county council by supplying or aiding the supply of, within their financial limits, higher education. In the non-county boroughs with a population of 10,000 and *under*, and urban districts with a population of 20,000 and *under*, the county council, in addition to its authority over higher education, controls elementary education. The act goes on to provide that the local educational authority shall 'take such steps as seem to them desirable, after consultation with the Board of Education, to supply or aid the supply of education other than elementary, and to promote the general coordination of all forms of education.' In order to fulfil this laudable purpose the local educational authority is invested with a rating power for secondary education to enable it to supplement the funds above referred to as ear-marked for secondary education. County borough councils can make any necessary rate for secondary education, but county councils can only make (apart from the consent of the Local Government Board to a higher rate) a rate of twopence in the pound (threepence in certain exceptional cases) while the councils of non-county boroughs and urban districts are able only to make a rate of one penny in the pound for this purpose. The religious aspect of higher education is made the subject of special provisions, and a carefully drafted conscience clause protects all classes of pupils.

Part III. of the act (sections 5–17) deals with elementary education. It abolishes school boards and substitutes the local education authority. This authority, in addition to the power of the old school boards over schools provided out of the rates, is responsible for and has the control of all secular education in these denominational schools

that have not been provided out of the rates and have hitherto been known as 'voluntary schools.' In future the rate-provided schools will be supplied with a body of managers, four of whom will be appointed by the local education authority and two by the minor local authority (such as the parish council), in whose area the school is situated. On the other hand, in the case of the non-provided or 'voluntary schools,' the managing body will consist of four managers, appointed as heretofore by the denomination to which the school belongs and of two managers appointed, as to one by the local educational authority and as to another by the 'minor local authority,' such as the parish council of the parish in which the school is situated. Thus, while for the first time publicly elected persons are included in the managing bodies of the voluntary schools, yet the private and original or foundation managers still retain the controlling voice in all matters of religion, so that there can be no possibility of a change in the denominational character of the school. This was mere justice, since many of these schools have been Church of England, or Wesleyan, or Roman Catholic, or Jewish, as the case may be, for nearly a century. The local education authority has, however, complete control over secular education in these schools. The managers must carry out all its directions as to secular instruction, including any directions with respect to the number and educational qualifications of the teachers to be employed for such instruction, and for the dismissal of any teacher on educational grounds. The local education authority has power to inspect the school, and its consent is required, in relation to the appointment and dismissal of teachers; but an appointment by the managers can only be objected to on educational grounds, while a teacher *can* be dismissed without the consent of the local educational authority, on grounds connected with the giving of religious instruction in the school. The managers of the voluntary school must provide the schoolhouse free of any charge and keep it in good repair subject to fair wear and tear in the course of its use as a public elementary school. Such wear and tear has to be made good by the local educational authority. The religious instruction given in a voluntary school shall be in accordance with the provisions (if any) of the trust-deed on the subject and shall be under the control of the managers with an appeal to the superior denominational authority if such appeal is provided for by the trust deed. Subject as above the local education authority has to maintain and keep efficient all public elementary schools within their area which are necessary (whether 'voluntary schools' or rate-provided schools) and has the control of all expenditure required for that purpose. The provision of new schools, a different system of government grants—paid, not to the managers, but

to the local education authority—and the constitution of education committees of councils having powers under the act are various further salient characteristics of this measure to which it is necessary to draw attention. In the case of the education committees it is to be noticed that the whole educational administrative work will be done by these committees which will possess all the educational powers of the council except that of raising a rate or borrowing money for education purposes.

It is perhaps impossible to exaggerate the importance of this act of Parliament. Doubtless it has certain defects, but they are defects inherent in any act that endeavors to reconcile interests that are apparently in conflict. The political dissenters declared themselves wronged because rate-aid was given to the voluntary schools without a corresponding control by the representatives of the rate payers. Only one third of the managers represent the rate payers in the managing body of a voluntary school, and the fact that the majority of the managers are still private persons is a source of grievance to a certain class of liberals. On the other hand the owners of voluntary schools think themselves aggrieved in the fact that managers, who may not represent the denomination to which the school belongs, should have any word as to the religious teaching. These owners think that the public have the best of the bargain; the public have gained complete control, through the local education authority, over the secular teaching in these schools, while the views of the owners and managers are continually kept before the public by the representatives of the rate payers or the managing body. All the old privacy is lost.

On the whole, however, a fair bargain has been struck. The owners of the schools have a guarantee given them that the denominational character of each school shall be preserved, and they in return have for most purposes (other than religious) handed over the school to a body representing the public—the local education authority, *i. e.*, the education committee of a publicly elected body. An effort all through the act is made to do justice to denominational bodies on the one hand and to secure absolutely efficient and coordinated education on the other, and on the whole the measure may be regarded as the great starting point of a new and beneficent educational system. London does not come within this scheme, but the metropolis is now being dealt with on the same lines by a bill 'to extend and adapt the Education Act, 1902, to London.' The educational authority for London will be the London County Council represented by an education committee composed of members of the council and representatives of the various London borough councils and of various metropolitan educational interests. This central educational body will exercise control over the metropolitan borough councils in their new capacity as managers of all public elementary schools provided by the County Council.

It is proposed that the borough councils shall have the power of appointing and dismissing teachers (though not of fixing their number, qualifications and salary) and of selecting the sites for any new elementary schools that the County Council decide to provide. The bill in these respects may perhaps be altered, and it is possible that members of the council will form a majority (as they do not in the unamended bill) on the education committee. In most other respects it is proposed to bring London within the act of last year and therefore under the final control, for all forms of education, of the Board of Education. However, little is certain yet except that the London school board will pass away and with it that competition between primary and secondary schools which has been the result of one of the less desirable aspects of the work of a board which has done much good and earnest work in London since 1870. Of course, none of the London board schools will cease to exist, nor will one single form of educational activity disappear. Only the name will be changed and the particular characteristics of certain schools will be altered. Schools that ought to be strictly secondary in character will be made secondary, while schools of a primary type will be compelled to keep to that type, but will also be dove-tailed into the nearest strictly secondary school. London will gain immensely by this, though admirers of the London school board system will feel keenly any reversal of the old and ruinous policy of forcing higher grade elementary education into competition with pure secondary education. Gain in efficiency is, however, the only thing to be considered, and there can be no doubt that the London school board has outgrown its functional usefulness and may well be replaced by a body capable of coordinating metropolitan education of all grades.

When the London bill is passed English education, whether primary, secondary, technical or tertiary, will be in a highly satisfactory state as far as machinery is concerned. The putting of this machinery into smooth motion will then be merely a question of time. When this is done the future of England may be regarded without pessimism or distrust. The widest meaning of education itself will gradually enter into the knowledge of the nation and it will be within the power of the poorest to reap harvests of incalculable wealth in hidden lands yet unknown to the masses of the people. Far away lie these lands, beyond the passionate, the stormy, the fretful, the cruel ocean of ignorance. All glory and honor will be to the generation that shall devise fit means of transit across this fearful region. The sea of ignorance imprisons the human race in a narrow land. Across its waters the few pass fitfully, fearfully now; but surely the day is not far distant when the many shall claim in pride and gladness their birthright of passage.

THE DECLINING BIRTH RATE AND ITS CAUSE.

By FREDERICK A. BUSHEE, Ph.D.,

CLARK COLLEGE.

IN the May number of The Popular Science Monthly Professor Thorndike discusses the question of the low birth rate among college graduates, presenting statistics from New York University, Middlebury College, and Wesleyan University, which confirm the report of President Eliot of Harvard University. These statistics show pretty conclusively that the birth rate among families of college graduates, at least in the east, is not large enough to keep up their numbers, and the question at once arises whether this tendency is confined to the intellectual classes or whether it applies to others as well. In either case it is of the utmost importance to understand the cause of the phenomenon. Let us consider then, first, the evidence of a low birth rate outside the circle of college graduates, and, secondly, let us consider the possible causes of a low birth rate.

The evidence concerning the natural increase of the population in this country is exceedingly meager. In the first place comparatively little attention has been given to the question here, because we have come to think that, though it is a question which France has to wrestle with, it has nothing to do with a new country like the United States. Again, owing to the different conditions existing in different districts, and to the different social conditions in the same district, a solution of the question would require detailed statistics which are not available for any large area of the United States. Very fair results may be obtained, however, by studying the population of a single state or city along national lines. The results which have already been obtained by this method in Massachusetts throw considerable light upon the question of the natural increase of our population.

Mr. Kuczynski, a Washington statistician, has made an exhaustive study of the statistics of Massachusetts and has concluded that the native population of Massachusetts is dying out.* His study extends over the period from 1885 to 1897. He shows, first, that the marriage rate among the natives is much smaller than among the foreign born for all ages up to 45. The marriage rate of unmarried males, 15 years of age and older, is, native born, 47.7; foreign born, 68.9; and for females, native born, 40, foreign born, 56.8. Secondly, the proportion of per-

* *Quarterly Journal of Economics*, November, 1901, February, 1902.

sons married among the natives is much smaller than among the foreign born, and the difference is particularly great at the most fruitful periods of life. Thirdly, the proportion of married women that have never had children is much greater among the natives than among the foreign born. It is one fifth among the natives and two fifteenths among foreigners. Fourthly, the birth rate among married women of child bearing age is much larger among foreign born. The figures are 142.47 per mille for natives and 251.76 for foreign born. Finally, an interesting result for our purpose is that for the period under discussion, 1885–1897, the marriage rate and the proportion of married women were decreasing among the natives and increasing among the foreigners. And the refined birth rates were fairly steady for the natives, but increasing for the foreign born.

As to the question of whether the native population is actually keeping up its numbers or not, after showing the paucity of our vital statistics as compared with those of Berlin, Mr. Kuczynski says, "But as the tables of fecundity of Berlin show that, with an annual special birth rate of ten for every hundred women in child-bearing age, in 1891–95, the births were one ninth behind the number necessary to keep the population of Berlin stationary, it is probable that the native population of Massachusetts, with a special birth rate of 6.3 births for every 100 adult women in child bearing age, and a mortality of the female sex not correspondingly lower than that of Berlin, can not only not hold its own, but is dying out at a considerable pace."* In studies which I have made upon the population of Boston by nationalities† practically the same results were obtained, although there was less opportunity to make a detailed study of the birth rates. The figures for Boston indicate that the negroes and the native whites are failing to keep up their numbers—the former on account of a high death rate and the latter on account of a low birth rate. On the other hand, all the foreign born groups show a natural increase, though the rate of increase varies greatly with the different nationalities. On the whole, the most recently immigrating nationalities have the highest birth rates.

The statistics, although somewhat fragmentary, seem to show that in Massachusetts, and probably also in other sections of the country having similar social conditions, the older part of the population, represented roughly by native Americans, is slowly dying out because of the low birth rate. If this is true the conditions in the older parts of the United States bear a strong resemblance to those in France, except that in the latter country the population as a whole fails to increase, while in this country it is only a section of the population. In the

* *Quarterly Journal of Economics*, February, 1902, p. 184.

† Publication *American Economic Association*, May, 1903.

United States, and even in Massachusetts, the population as a whole is increasing, but the increase is confined for the most part apparently to the immigrating classes. Inasmuch as the failure to increase is confined to only a part of the population in the United States, it is extremely difficult to ascertain the exact situation by statistical means. An insidious loss may be going on in a particular direction and still be undiscovered because of defective mortality statistics.

These statistics put the whole native population of Massachusetts in the same position as college graduates, and the question accordingly seems to be one of the upper class or of the older part of the population and not simply a question of the educated classes.

In the absence of further statistics upon the subject, it will be of assistance to ascertain, by theoretical law if possible, the causes which contribute to these suicidal tendencies in the population. Laws of population have been formulated from similar experiences in other countries, and among these laws we may find one which will throw light upon our own situation.

It will not be worth while to review the common theories of population and show their application to our present conditions. The theory of Malthus, or even that of Spencer, will be of little avail, as the birth rate in the United States is not greatly affected by physical causes. And, although some writers have pointed to a possible biological cause, it is improbable that in a new country like the United States even the older part of the population could, as a class, be losing its fertility, when in so many of the older countries the fertility of the population is still good.

To social causes, primarily, are due the differences in the fecundity of civilized peoples. Therefore I shall present what may be called a social law of population. From the nature of the case any law of population must be exceedingly general, because a great number of conditions directly or indirectly affect the birth rate, and these secondary causes differ in different localities. The law which I am about to consider explains the situation only in a general way. Some of the special conditions which affect the birth rate here I shall discuss later on. This law of population is one formulated by a French student of demography, Arséne Dumont. In brief M. Dumont's theory is that population increases inversely with 'social capillarity.' This expressive phrase is almost self-explanatory. Among progressive peoples a strong tendency exists for men to improve their condition, and in a democratic country society yields somewhat to efforts in this line. If competition is severe it will be necessary for men to make a great effort to raise their standard of living, or sometimes, even to maintain the accustomed standard. Population is regulated by the intensity of the effort made.

Of course the check to population resulting from the desire for social betterment is a purely voluntary one, yet it is a good example of a social law that men under certain conditions will choose to refrain from having large families.

In applying this law it must be borne in mind that conditions vary greatly with different individuals and with different countries. If a man is able to raise his standard of living without great exertion, as is usually the case in a new country, no check to population may be expected. Or, if a man by exceptional abilities is able to maintain a high standard of living with comparative ease, he will not be influenced by the same considerations as the average man. If, on the one hand, men who easily raise their standard of living propagate freely, those who are unable to change their social position at all also propagate freely. In a caste system of society, or in an absolute despotism like that of Russia, the lower classes propagate blindly because they see no possibility of rising. No 'social capillarity' exists for them. In other words population is not held in check by a social law, but by a physical one. It is limited by the means of subsistence, according to the Malthusian law. Even among the lower classes of a great industrial center the same principle acts. Unskilled laborers attain the maximum wage at an early age and increased efforts on their part affect their social condition so little that they do not feel the social check and therefore propagate recklessly from hopelessness. A man in the lowest social class has no social position to lose, and only the best equipped can improve their condition sufficiently to feel the social restriction on population. To advise the laboring classes to limit their numbers in order to improve their condition, as the old economists did, is putting the cart before the horse. When the economic condition of the lowest industrial class improves enough to give its members some hope, they will begin to limit their numbers voluntarily in order further to improve their condition.

If, then, the class that rises easily in the social scale and the class which does not rise at all propagate freely the social check applies to that large class which rises, though only with great effort. It would appear then that in a pure democracy where increased reward always followed increased effort, the population would regulate itself automatically, because increased population would increase competition and that would bring about the social check. Its application to some of our large cities will be readily understood by those who are acquainted with the social conditions existing in them. Their enormous increase of population has increased competition to such an extent that only the best equipped—as compared with other members of the same class, not with inferior classes—can easily maintain the standard of living

set by their own particular classes. Consequently the cares of a family are deferred. If one enters the lodging houses in the south and west ends of Boston, for example, one will find a large class of lodgers from northern New England and from the British Provinces, the majority of whom are not married and never will be. This class represents a part of the population which is refraining from marriage in order to keep up its social position. In the words of M. Dumont, 'social capillarity' is so strong that they refrain from marriage. This state of affairs is unfortunate for the future good of the city. Cities have come to depend upon fresh blood from the country to reinforce their declining stock, and there is no reason to believe that former immigrants from rural sections found it necessary to refrain from marriage as the present immigrants do. In other words, a change is taking place in the character of the population of large cities which only the next generation will realize. Cities of the present time are making use of rural Americans and also of the children of rural Americans who came to the city about the middle of the nineteenth century. In the next generation the proportion of children of rural immigrants will be greatly reduced, and the probabilities are that the largest cities will offer small inducements for the immigration of rural Americans.

With this application of the general law of population I pass to the discussion of two conditions in the eastern part of the United States which tend to intensify the action of this law and make the birth rate in this new country as low as it is in some of the old European countries. First, the increased competition which naturally results from a growing population has been augmented by the entrance of women into industrial pursuits. As women find fewer opportunities for marriage, they throw themselves into industrial life, and by their increased competition make the possibility of marriage even more remote. As writers have frequently noted the depression of wages resulting from the competition of women, however, I will pass on to the second phenomenon which affects the social law of population—that is, immigration. Competition resulting from increased population is much more serious if it is caused by the incoming of classes on a different social plane. Irish, Italian, and Jewish immigrants compete indirectly, and frequently directly with American labor, yet these immigrants live in a different world and under different conditions from the American laborer. Most foreigners form a stratum below Americans. Between the lodging house and the tenement is a wide gap which is not paralleled by an industrial separation. Americans in lodging houses are not attempting so much to raise their standard as they are to retain the accustomed standard of their homes and to save themselves from falling into the social position of the foreign population.

When Francis Walker was director of the United States Census, he went so far as to maintain that the population of the country would have been just as large if there had been no foreign immigration, since the older American elements would then have multiplied much more rapidly than they have. This is without doubt an extreme statement, yet it is true that the multiplication of foreign peoples has seriously checked the growth of the old American stock. It may be that in the distant future the mixture of all the European peoples will produce a race superior to any we have yet seen. It is well to bear in mind, however, that in forming a race of unknown value, there is being sacrificed a race of acknowledged superiority in originality and enterprise.

The relative decrease of the native stock is, however, far more noticeable than its absolute decrease. For example, from the last statistics available for Boston it appears that the Russian Jews increased by propagation 25 per cent. between 1890 and 1895, and the Italians increased 21 per cent. during the same period, while the native born decreased slightly. And this phenomenal natural increase of the Italians and the Jews takes on an added significance from the fact that during the same period of five years the Italians increased 67 per cent. and the Jews 51 per cent. by immigration.

Foreign immigrants, after being in this country for some time, seem to be affected in much the same way as the native born. However, the pressure of competition from recent immigration does not affect them so much as it does the greater part of the native born, for a greater social cleavage exists between the rural Americans and foreign immigrants than between the old and new immigrants. Yet the Irish and the Germans, at least in Boston, have a much smaller birth rate than the Italians and the Jews, and also than they themselves had in 1850.

Mr. Kuczynski, in his study of Massachusetts, continually contrasts the statistics for the native born with those for the foreign born, but there is more than a contrast, there is a causal connection. The rapid influx of foreigners and their unrestrained increase necessarily affects the native born. And the evil effects arise from the competition in industrial pursuits of people of different social standards. If the immigrants were of the same ideals and standards as the native Americans, the results would be different. The increased competition would bring about a lowering of the birth rate, but the restraint would be mutual to both natives and foreigners. In the present case, however, where the standards are different the prudential restraint is exercised only by the group which has a social standard to maintain. Is it not from a sense of self preservation that castes tend to be formed in a society consisting of distinct social classes, so that each caste shall have its separate sphere of employment and competition between castes

shall be eliminated as much as possible? Otherwise the upper classes would tend to be obliterated by the competition of the lower classes.

To sum up, then, we may say that the study of the statistics available in the light of recent theories of population gives us a reasonable understanding of the natural increase of the population. Statistics show that in Massachusetts at least the native population which includes the upper classes is losing ground. That this loss is due to the effort necessary to maintain or raise the social position caused by strong competition is shown by the fact that the marriage rate as well as the birth rate is low. This competition is caused largely by the influx of foreigners who tend to compete with the natives, but do not share with them the dread of lowering the social standard. If the increased population came wholly from within the state, the population would tend to regulate itself automatically, but when the increase is largely imposed upon a state from without, and this foreign element reproduces itself rapidly it may have a serious influence upon the native population without being very apparent. The economic question is by no means the most important one to consider in the problem of immigration. It is a race question and the birth rate shows the racial group that is to survive. If, however, it is found that the stratum of society which has the highest development tends to be blotted out by the increase of the lower strata, the cause of progress will demand that the course of natural selection be interfered with by removing the continual external pressure on the native stock.

HERTZIAN WAVE WIRELESS TELEGRAPHY. III.

By Dr. J. A. FLEMING, F.R.S.,

PROFESSOR OF ELECTRICAL ENGINEERING, UNIVERSITY COLLEGE, LONDON.

WE have to consider in connection with this part of the subject the dielectric strength of air under different pressures and for different thicknesses. It was shown by Lord Kelvin, in 1860, that the dielectric strength of very thin layers of air is greater than that of thick layers.* The electric force, reckoned in volts per centimeter, required to pierce a thickness of air from two to ten millimeters in thickness, at atmospheric pressure, may be taken at 30,000 volts per centimeter. The same force in electrostatic units is represented by the number 100, since a gradient of 300 volts per centimeter corresponds to a force of one electrostatic unit. It appears also that for air and other gases, there is a certain minimum voltage (approximately 400 volts) below which no discharge takes place, however near the conducting surfaces may be approximated. In this particular practical application, however, we are only concerned with spark lengths which are measured in millimeters or centimeters, lying say between one or two millimeters and five or six centimeters. Over this range of spark length we shall not generally be wrong in reckoning the voltage required to produce a spark between metal balls in air at the ordinary pressure to be given by the rule:

Disruptive voltage $=$ 3000 $\times$ *spark gap length in millimeters.*

If, however, the air pressure is increased above the normal by including the spark balls in a vessel in which air can be compressed, then the spark length corresponding to a given potential difference very rapidly decreases. Mr. F. J. Jervis-Smith† found that by increasing the air pressure from one atmosphere to two atmospheres round a pair of spark balls, he reduced the spark length given by a certain voltage from 2.5 cm. to 0.75 cm.

Professor R. A. Fessenden has also made some interesting observations on the effect of using compressed air round spark gaps. He

* See *Proc. Roy. Soc.*, London, February 23 and April 12, 1860; or reprint of papers on electrostatics and magnetism, p. 247.

† See *Phil. Mag.*, August, 1902, Vol. IV., p. 224, 6th Series. Mr. Jervis-Smith has also described an experiment to show how much the use of compressed air round a spark gap is of advantage in working an ordinary Tesla coil. In his British specification No. 12,039 of 1896, Mr. Marconi had long previously mentioned the use of compressed air round the spark gap.

found that if a certain voltage between metal surfaces would yield a spark four inches in length, at the ordinary pressure of the air, if the spark balls were enclosed in a cylinder, the air round them compressed at 50 lbs. per square inch, the spark length for the same potential difference of the balls was only one quarter of an inch, or one sixteenth of its former value.

The writer has also made experiments with an apparatus designed to study the effect of compressed air round the spark gap. The experimental arrangements are as follows: A ten-inch induction coil has one of its terminals connected to the internal coating of a battery of Leyden jars. The external coating is connected through the primary coil of an oscillation transformer with the other secondary terminal of the coil, and these secondary terminals are also connected to a spark gap consisting of two brass balls enclosed in a glass vessel into which air can be forced by a pump, the air pressure being measured by a gauge. The balls in the glass vessel are set at a distance of about three millimeters apart. The secondary circuit of the oscillation transformer is connected to another pair of spark balls, the distance of which can be varied.

Suppose we begin with the air in the glass vessel containing the balls connected to the secondary terminals of the induction coil, which may be called the secondary balls, at atmospheric pressure, and create oscillatory discharges in the primary coil of the oscillation transformer, we have a spark between the balls, which may be called the tertiary balls, connected to the secondary terminals of the oscillation transformer. If the secondary balls are placed, say three millimeters apart, the air in the glass vessel enclosing them being at the ordinary atmospheric pressure, then with one particular arrangement of jars used, a spark twenty-five or twenty-six millimeters long between the tertiary balls will take place. Suppose then we increase the pressure of the air round the secondary balls, pumping it up by degrees to 10, 20, 30, 40 and 50 lbs., per square inch, above the atmospheric pressure. We find that the spark between the tertiary balls will gradually leap a greater and greater distance, and when the pressure of the air is 50 lbs. per square inch, we can obtain a fifty-millimeter spark between the tertiary balls, whereas when the air in the glass vessel is at atmospheric pressure, we can only obtain a spark between the tertiary balls of half that length.

This experiment demonstrates that the effect of compressing the air round the secondary terminals of the induction coil is to greatly increase the difference of potential between these balls before the spark passes. In fact, it requires about double the voltage to force a spark of the same length through air compressed at 50 lbs. on the square inch that it does to make a spark of identical length between the

same balls in air at normal pressure. This shows that there is a very great advantage in taking the discharge spark in compressed air. A better effect can be produced by substituting dry gaseous hydrochloric acid for air at ordinary pressures.

One other incidental advantage is that the noise of the spark is very much reduced. The continual crackle of the discharge spark of the induction coil in connection with wireless telegraphy is very annoying to sensitive ears, but in this manner we can render it perfectly silent.

Professor Fessenden also states that when the spark balls are surrounded by compressed air, and if one of the balls is connected with a radiator, the compression of the air, although it shortens the spark gap corresponding to a given voltage, does not in any way increase the radiation. When, however, the air in the spark ball vessel is compressed to 60 lbs. in the square inch, there is a marked increase in the effective radiation, and at 80 lbs. per square inch the energy emitted in the form of waves is nearly three and a half times greater than at 50 lbs., the potential difference between the balls remaining the same.

This effect is no doubt connected with the fact that the production of a wave, whether in ether or in any other material, is not so much dependent upon the absolute force applied as upon the suddenness of its application. To translate it into the language of the electronic theory, we may say that the electron radiates only whilst it is being accelerated, and that its radiating power, therefore, depends not so much upon its motion as upon the rate at which its motion is changing.

The advantage in using compressed air round the spark gap is that we can increase the effective potential difference between the balls without rendering the spark non-oscillatory. In air of the ordinary pressure there is a certain well-defined limit of spark length for each voltage, beyond which the discharge becomes non-oscillatory, but by the employment of spark balls in compressed air, we can increase the potential difference between the balls corresponding to a given distance apart before a discharge takes place, or employ higher potentials with the same length of spark gap. In addition to this, we have, perhaps, the production of a more effective radiation, as asserted by Fessenden, when the air pressure exceeds a certain critical value.

The next element which we have to consider in the transmitting arrangements is a condenser of some kind for storing the energy which is radiated at intervals. Where a condenser other than the aerial is employed for storing the electric energy which is to be radiated by the aerial, some form of it must be constructed which will withstand high potentials. As the dielectric for such a condenser, only two materials seem to be of any practical use, viz., glass and micanite.

Glass condensers in the form of Leyden jars have been extensively employed, but they have the disadvantage that they are very bulky in proportion to their electrical capacity. The instrument maker's quart Leyden jar has a capacity of about one five hundredth of a microfarad, but it occupies about 150 cubic inches or more. Professor Braun has employed in his transmitting arrangements condensers consisting of small glass tubes like test tubes, lined on the inside and outside with tinfoil, which are more economical in space. The author has found that condensers for this purpose are best made of sheet glass about one eighth or one tenth of an inch in thickness, coated to within one inch of their edge on both sides with tinfoil, and arranged in a vessel containing resin or linseed oil, like the plates of a storage battery. M. d'Arsonval has employed micanite, but although this material has a considerably higher dielectric strength than glass, it is much more expensive to obtain a given capacity by means of micanite than by glass, although the bulk of the condenser for a given capacity is less.

To store up a certain amount of electric energy in a condenser, we require a certain definite volume of dielectric, no matter how we may arrange it, and the volume required per unit of energy is determined by the dielectric strength of the material. Thus, for instance, ordinary sheet glass can not be safely employed with a greater electric force than is represented by 20,000 volts for one tenth of an inch in thickness, or say a potential gradient of 160,000 volts per centimeter. This is equivalent to an electric force of about 500 electrostatic units. This may be called the safe-working force. The electrostatic capacity of a condenser formed of two metal surfaces a foot square separated by glass three millimeters in thickness is between 1/360 and 1/400 of a microfarad. If this condenser is charged to 20,000 volts, we have stored up in it half a joule of electric energy, and the volume of the dielectric is 270 cubic centimeters. Hence to store up in a glass condenser electric energy represented by one joule at a pressure of 20,000 volts, we require 500 cubic centimeters of glass, and it will be found that if we double the pressure and double the thickness of the glass, we still require the same volume.* Hence in the construction of high tension condensers to store up a given amount of energy, the economical problem is how to obtain the greatest energy-storing capacity for the least money. Glass fulfils this condition better than any other material. Although some materials may have very high dielectric strength, such as paper saturated with various oils, or resins, yet they can not be used for the purpose of making condensers to yield oscillatory discharges,

* This energy storage is at the rate of 44 foot-pounds per cubic foot of glass. This figure shows what a relatively small amount of energy is capable of being stored up in the form of electric strain in glass. In the case of an air condenser, it is only stored at the rate of one foot-pound per cubic foot.

because the oscillations are damped out of existence too soon by the dielectric.

In arranging condensers to attain a given capacity, regard has to be taken of the fact that for a given potential difference there must be a certain total thickness of dielectric, and that if condensers of equal size are being arranged in parallel, it adds to their capacity, whilst joining them in series divides their capacity. If N equal condensers or Leyden jars have each a capacity represented by C and if they are joined n in series and m in parallel, the joint capacity of the whole number is mC/n, where the product $mn = N$.

Passing on next to the consideration of oscillation transformers of various kinds—these are appliances of the nature of induction coils for transforming the current or electromotive force of electrical oscillations in a required ratio. These coils are however destitute of any iron core, and they generally consist of coils of wire wound on a fiber, wooden or ebonite frame, and must be immersed in a vat of oil to preserve the necessary insulation. No dry insulation of the nature of indiarubber or guttapercha will withstand the high pressures that are brought to bear upon the circuits of an oscillation transformer. In constructing these transformers, we have to set aside all previous notions gathered from the design of low frequency iron core transformers. The chief difficulty we have to contend against in the construction of an effective oscillation transformer is the inductance of the primary circuit and the magnetic leakage that takes place. In other words, the failure of the whole of the flux generated by the primary circuit to pass through or be linked with the secondary circuit. Mr. Marconi has employed an excellent form of oscillation transformer, in the design of which he was guided by a large amount of experience. In this transformer the two circuits are wound round a square wooden frame. The primary circuit consists of a number of strands of thick insulated cable laid on in parallel, so that it consists of only one turn of a stranded conductor. The secondary circuit consists of a number of turns, say ten to twenty, of thinner insulated wire laid over the primary circuit and close to it, so that the transformer has the transformation ratio of one to ten or one to twenty. In the arrangements devised and patented by Mr. Marconi, these two circuits, with their respective capacities in series with them, are tuned to one another, so that the time-period of each circuit is exactly the same, and without this tuning the device becomes ineffective as a transformer.* There is no advantage in putting a number of turns on the primary circuit, because such multiplication simply increases the inductance, and, therefore, diminishes the primary current in the same ratio which it multiplies the

* See British specification No. 7,777 of 1900—G. Marconi. 'Improvements in Apparatus for Wireless Telegraphy.'

turns, and hence the magnetic field due to the primary circuit remains the same. Where it is desired to put a number of turns upon a coil, and yet at the same time keep the inductance down, the writer has adopted the device of winding a silk or hemp rope well paraffined between the turns of the circuit, so as to keep them further apart from one another, and as the inductance depends on the turns per centimeter, this has the effect of reducing the inductance.

The next and most important element in any transmitting station is the aerial or radiator, and it was the introduction of this element by Mr. Marconi which laid the foundation for Hertzian wave telegraphy as opposed to mere experiments with the Hertzian waves. We may consider the different varieties of aerial which have been evolved from the fundamental idea. The simple single Marconi aerial consists of a bare or insulated wire, generally about 100 or 150 feet in length, suspended from a sprit attached to a tall mast. As these masts have generally to be erected in exposed positions, considerable care has to be taken in erecting them with a large margin of strength. To the end of a sprit is attached an insulator of some kind which may be a simple ebonite rod, or sometimes a more elaborate arrangement of oil insulators, and to the lower end of this insulator is attached the aerial wire. As at the top of the aerial we have to deal with potentials capable sometimes of giving sparks several feet in length, the insulation of the upper end of the aerial is an important matter.

In the original Marconi system, the lower end of the aerial was simply attached to one spark ball connected to one terminal of the induction coil, and the other terminal and spark ball were connected to the earth. In this arrangement, the aerial acted not only as radiator, but as energy-storing capacity, and as already explained, its radiating power was on that account limited. The earth connection is an important matter. For long distance work, a good earth is essential. This earth must be made by embedding a metal plate in the soil, and many persons are under the impression that the efficiency of the earth plate depends upon its area, but this is not the fact. It depends much more upon its shape, and principally upon the amount of its 'edge.' It has been shown by Professor A. Tanakadate, of Japan, that if a metal plate of negligible resistance is embedded in an infinite medium having a resistivity r, the electrical conductance of this plate is equal to $4\pi/r$ times the electrostatic capacity of the same plate placed in a dielectric of infinite extent. Hence in designing an earth plate, we have to consider not how to give it the utmost amount of surface, but how to give it the greatest electrostatic capacity, and for this purpose it is far better to divide a given amount of metal into long strips radiating out in different directions, rather than to employ it in the form of one big square or circular plate.

The importance of the 'good earth' will have been seen from our discussion on the mode of formation of electric waves. There must be a perfectly free access for the electrons to pass into and out of the aerial. Hence if the soil is dry, or badly conductive in the neighborhood, we have to go down to a level at which we get a good moist earth. In fact, the precautions which have to be taken in making a good earth for Hertzian wave telegraphy are exactly those which should be taken in making a good earth for a lightning conductor.

Whilst on the subject of aerials, a word may be said on the localization of wireless telegraph stations on the Marconi system. For reasons which were explained previously, the transmission of signals is effected more easily over water than over dry land, and it is hindered if the soil in the neighborhood of the sending station is a poor conductor. Hence all active Hertzian wave telegraph stations, like all active volcanoes, are generally found near the sea. In those cases in which a multiple aerial has to be put up consisting of many wires, one mast may be insufficient to support the structure, and several masts arranged in the form of a square or a circle have to be employed. The illustrated papers have reproduced numerous pictures of the Marconi power stations at Poldhu in Cornwall, Glace Bay in Nova Scotia, and Cape Cod in the United States. In these stations, after preliminary failures to obtain the necessary structural strength with ordinary masts, tall lattice girder wooden towers have been built, about 215 feet in height, well stayed against wind pressure, and which so far have proved themselves capable of withstanding any storm of wind which has come against them.

An important question in connection with the sending power of an aerial is that of the relation of its height to the distance covered. Some time ago Mr. Marconi enunciated a law as the result of his experiments, connecting these two quantities, which may be called Marconi's Law. He stated that the height of the aerial to cover a given distance, other things remaining the same, varies as the square root of the distance. Let D be the distance and let L be the length of the aerial, then if both the transmitting and receiving aerial are the same height, we may say that D varies as L^2. This relation may be theoretically deduced as follows: Any given receiving apparatus for Hertzian wave telegraphy requires a certain minimum energy to be imparted to it to make it yield a signal. If the resistance and the capacity of the receiver is taken as constant, this minimum working energy is proportional to the square of the electromotive force set up in the receiving aerial by the impact on it of the electric waves. This electromotive force varies as the length of the receiving aerial, and as the magnetic force due to the wave cutting across it, and the magnetic force varies as the current in the transmitting aerial, and

therefore for any given voltage varies as the capacity, and therefore as the length of the transmitting aerial. If, therefore, the transmitting and receiving aerial have the same length, the minimum energy varies as the square of the electromotive force in the receiving aerial, and therefore as the fourth power of the length of either aerial, since the electromotive force varies as the product of the lengths of the aerials. Hence when the distance between the aerials is constant, the minimum working energy varies as the fourth power of the height of either aerial, but when the lengths of the aerials are constant, the energy caught up by the receiving aerial must vary inversely as the square of the distance D between the aerials. Hence if we call e this minimum working energy, e must vary as $1/D^2$ when L is constant, or as L^4 when D is constant, and since e is a constant quantity for any given arrangements of receiver and transmitter, it follows that when the height of aerial and distance vary, the ratio L^4/D^2 is constant, or, in other words, D^2 varies as L^4 or D varies as L^2, *i. e.*, distance varies as the square of the height of the aerial, which is Marconi's Law. The curve therefore connecting height of aerial with sending distance for given arrangements is a portion of a parabola.

Otherwise, the law may be stated in the form $L = a\sqrt{D}$, where a is a numerical coefficient. If L and D are both measured in meters, then for recent Marconi apparatus as used on ships $a = 0.15$, roughly. (See a report on experiments made for the Italian navy 1900–1901, by Captain Quintino Bonomo—'Telegrafia senza fili,' Rome, 1902.)

This law, however, must not be used without discretion. After Mr. Marconi had transmitted signals across the British Channel, some people, forgetting that a little knowledge is a dangerous thing, predicted that aerials a thousand feet in height would be required to signal across the Atlantic, but Mr. Marconi has made such improvements of late years in the receiving arrangements that he has been able to receive signals over three thousand miles in 1903, with aerials only thirty-three per cent. longer than those which, in 1899, he employed to cover twenty miles across the British Channel.

We turn, in the next place, to the consideration of those devices for putting more power into the aerial than can be achieved when the aerial itself is simply employed as the reservoir of energy. Professor Braun of Strasburg, in 1899, described a method for doing this by inducing oscillations in the aerial by means of an oscillation transformer, these oscillations being set up by the discharges from a Leyden jar or battery of Leyden jars, which formed the reservoir of energy. The induction coil is employed to produce a rapidly intermittent series of electrical oscillations in the primary coil of an oscillation transformer by the discharge through it of a Leyden jar. Mr. Marconi

immensely improved this arrangement, as described by him in a lecture given before the Society of Arts, on May 17, 1901, by syntonizing the two circuits and making the circuit, consisting of the capacity of the aerial and the inductance of the secondary circuit of the oscillation transformer, have the same time-period as the circuit consisting of the Leyden jars, or energy-storing condenser, and the primary circuit of the oscillation transformer, and by so doing immensely added to the power and range of the apparatus.

Starting from these inventions of Braun and Marconi, the author devised a double transmission system in which the oscillations are twice transformed before being generated in the aerial, each time with a multiplication of electromotive force, and a multiplication of the number of groups of oscillations per second. This arrangement can best be understood from the diagram (see Fig. 15).

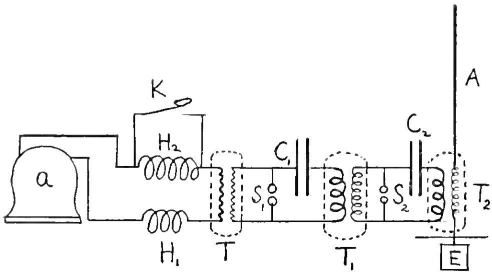


FIG. 15. ALTERNATING CURRENT DOUBLE TRANSFORMATION POWER PLANT FOR GENERATING ELECTRIC WAVES (Fleming). a, alternator; H_1H_2, choking coil; K, signaling key; T, step-up transformer; S_1S_2, spark gap; C_1C_2, condensers; T_1T_2, oscillation transformers; A, aerial; E, earthplate.

In this case, a transformer T or transformers, receive alternating low frequency current from an alternator a, being regulated by passing through two variable choking coils, H_1 and H_2, so as to control it. This alternating current is transformed up from a potential of two thousand to twenty, forty or a hundred thousand, and is employed to charge a large condenser C_1, which discharges across a primary spark gap S_1 through the primary coil of an oscillation transformer T_1. The secondary circuit of the oscillation transformer is connected to a second pair of spark balls S_2, which in turn are connected by a secondary condenser C_2, and the primary circuit of a third transformer T_2, and the secondary circuit of this last transformer are inserted between a Marconi aerial A and the earth E. When all these circuits are tuned to resonance by Mr. Marconi's methods, we have an enormously powerful arrangement for creating electric waves, or rather trains of electric waves, sent out from the aerial, and the oscillations are controlled and the signals made by short-circuiting one of the choking coils.

Another transmitting arrangement, which involves a slightly different principle, and employs no oscillation transformer, is one due

also to Professor Braun. In this case, a condenser and inductance are connected in series to the spark balls of an induction coil, and oscillations are set up in this circuit. Accordingly, there are rapid fluctuations of potential at one terminal of the condenser. If to this we connect a long aerial, the length of which has been adjusted to be one quarter of the length of wave corresponding to the frequency, in other words, to make it a quarter wave resonator, then powerful oscillations will be accumulated in this rod. The relation between the height (H) of the aerial and the frequency, is given by the equation $3 \times 10^{10} = 4nH$, where n is the frequency of the oscillations and H the height of the aerial in centimeters. The frequency of the oscillations is determined by the capacity (C) and inductance (L) of the condenser circuit, and can be calculated from the formula

$$n = \frac{5{,}000{,}000}{\sqrt{C\,(\text{in mfds.}) \times L\,(\text{in cms.})}}.$$

That is, the frequency is obtained by dividing into the number 5,000,000, the square root of the product of the capacity in microfarads, and inductance in centimeters, of the condenser circuit. It will be found, on applying these rules, that it is impossible to unite together any aerial of a length obtainable in practise with a condenser circuit of more than a very moderate capacity. It has been shown that for an aerial two hundred feet in height the corresponding resonating frequency is about one and a quarter million.* As we are limited in the amount to which we can reduce the inductance of a discharge circuit, probably to something like a thousand centimeters, a simple calculation shows that the largest capacity we can employ is about a sixtieth of a microfarad. This capacity, even if charged at 60,000 volts, would only contain thirty joules of energy, or about 22.5 foot-pounds, which is a small storage compared to that which can be achieved when we are employing the above described methods, which involve the use of an oscillation transformer. In such a case, however, it is an advantage to employ a spark gap in compressed air, because we can then raise the voltage to a much higher value than in air of ordinary pressure without lengthening the spark so much as to render it non-oscillatory.

When employing methods involving the use of an oscillation transformer, it is possible to use multiple aerials having large capacity, and hence to store up a very large amount of energy in the aerial, which is liberated at each discharge. The most effective arrangement is one

* That this number really does represent the order of this oscillation frequency in an aerial has been shown by C. Tissot, *Comptes Rendus*, 132, p. 763, March 25, 1901, by photographs taken of the oscillatory spark of a Hertzian wave telegraphic transmitter. (See *Science Abstracts*, Vol. IV., Abs. 1518.) He found frequencies from 0.5 million to 1.6 million.

in which the radiator draws off gradually a large supply of energy from a non-radiating circuit, and so sends out a true train of waves, and not mere impulses, into the ether, and as we shall see later on, it is only when the radiation takes place in the form of true wave trains that anything like syntony can be obtained.

There are a number of variants of the above methods of arranging the radiator and associated energy-storing in circuit. Descriptions of these arrangements will be found in patents by Mr. Marconi, Professor Slaby and Count von Arco, Sir Oliver Lodge, Dr. Muirhead, Professor Popoff, Professor Fessenden and others. In all cases, however, they are variations of the three simple forms of radiator already described.

Returning to the analogy with the air or steam siren suggested at the commencement of this article, the reader will see, in the light of the explanations already given, that all parts of the air wave producing apparatus have their analogues in the electrical radiator as used in Hertzian wave telegraphy. The object in the one case is to produce rapid oscillations of air particles in a tube, which result in the production of an air wave in external space; in the other case, the arrangement serves to produce oscillations of electrons or electrical particles in a wire, the movements of which create a disturbance in the ether called an electrical wave. Comparing together, item by item, it will be seen, therefore, that the induction coil or transformer used in connection with electric wave apparatus is analogous to the air pump in the siren plant. In the electrical apparatus, this electron pump is employed to put an electrical charge into a condenser; in the air wave apparatus, the air pump is employed to charge an air vessel with high pressure air. From the electrical condenser the charge is released in the form of a series of electrical oscillations, and in the air wave producing appliance, the compressed air is released in the form of a series of intermittent puffs or blasts. In the electrical wave producing apparatus, these electrical oscillations in the condenser circuit are finally made to produce other oscillations in an air wire or open circuit, just as the puffs of air finally expend themselves in producing aerial oscillations in the siren tube. Finally, in the one case we have a series of air waves and in the other case, a series of electrical waves. These trains of electric waves or air waves, as the case may be, are intermitted into long and short groups, in accordance with the signals of the Morse alphabet, and therefore the Hertzian wave transmitter, in whatever form it may be employed, when operated by means of a Marconi aerial, is in fact an electrical siren apparatus, the function of which is to create periodic disturbances in the universal ether of the same character as those which the siren produces in atmospheric air.

(To be continued.)

DISCUSSION AND CORRESPONDENCE.

THE BIRTH RATE IN FICTION.

As the question of the size of family appears to be much discussed just now, I should like to call attention to the low birth rate in novels and plays, which, united as it is with a high death rate, will inevitably lead to the rapid extermination of the hero and heroine. I am under the impression also that the birth rate is decreasing, and while families of a respectable size may be found occasionally in Thackeray and Dickens, they scarcely exist in Meredith, Hardy and James. Although, so far as I am aware, attention has never been called to the alarming conditions, their existence will be recognized readily by readers of novels and play-goers. It will suffice to refer to two novels, which I think are fairly typical—'Vanity Fair' and 'Beauchamp's Career.'

Becky Sharp was an only child, nor do we hear of uncles or aunts. 'Vanity Fair' is a novel without a hero. Sir Pitt Crawley, twice married, has four children, his brother five and his sister none; so there is an average family of three, just sufficient to maintain that questionable line. Osborne and Dobbin each have two sisters, and we have again the family required for a stationary population. The Sedley family consists of brother and sister. In the next generation, however, things are worse. Amelia has two husbands and two children, Becky one child, Sir Pitt one and Josh none. This is apparently an average family of 1.83, which is almost exactly that of the Harvard graduates, according to President Eliot.

In 'Beauchamp's Career' Nevil is an only child and leaves a child to survive him; Everard Romfrey, marrying childless Mrs. Culling, has one child who dies in infancy; his brother has none; old Mrs. Beauchamp has none. Austin, Baskelett, Lydiard and Dr. Shrapnel leave no posterity. Of the three heroines, Jenny and Cecilia are only children; Renée is of the typical French family of two, but has herself no children. This is obviously a very bad state of affairs—an average family of one half child and a net fertility of only 0.43. As these statistics have been collected in large measure from a fallible memory, they may not be exactly correct, and they may not be entirely representative, but I am confident that they would be substantially confirmed by more accurate and extensive data. They certainly foretell the rapid extermination of the population of the novel.

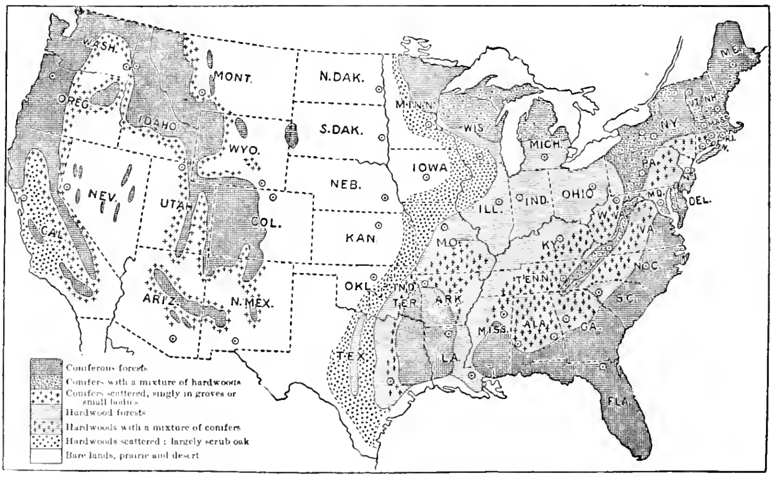
The conditions appear to be still worse in the drama. It is true that here the marriage rate is high, and something may be left to the imagination. But Hamlet, Macbeth, Othello and Romeo have no lines of descent, nor does Lear, though he has three daughters. In the current play the woman with a past may occasionally have a child; she certainly never has the average family of four to five; but her extermination is not so deplorable.

C.

SCIENTIFIC LITERATURE.

FORESTRY.

The people of the country are rapidly awakening to the immense economic importance of our forests and to the dangerous rapidity with which they are being exterminated. Germany and other countries have long maintained strict forestry systems and schools for foresters; our own resources were so great that there seemed to be no need of economy. But we are now told that the forests under present methods will scarcely last for thirty years, and there is a general demand for more knowledge and better management. In the past few years the Bureau of Forestry under the national government has grown rapidly, the appropriation for investigation having increased from $80,000 in 1901 to $254,000 for the present year. Schools of forestry have been established at Cornell, Yale and Harvard—we may be sure that New York state will soon repent its attitude toward the school at Cornell—and there is a general awakening of interest in the whole subject.



Forest Map of the United States.

Under these circumstances a little book recently issued by Ginn and Company, entitled 'First Book of Forestry,' is more deserving of notice than other works of greater pretensions. The author, Mr. Filbert Roth, of the Bureau of Forestry, is an authority on the subject, and is able to put it in a simple and interesting form. The book is just what is needed as a tract, and it is to be hoped that it will be widely read.

THE PROGRESS OF SCIENCE.

THE BOSTON MEETING OF THE NATIONAL EDUCATIONAL ASSOCIATION.

It is usual for each meeting of the National Educational Association to show an attendance and to claim a success surpassing its predecessors, but the recent Boston meeting established a record that has not hitherto been approached and that will not soon be challenged. It is said that there was a registration of thirty thousand, an assemblage of teachers larger than the world has hitherto seen. Boston is no longer without rival as an intellectual center, but its preeminence in the history of education is maintained, and the intellectual and educational interests of the city are not submerged and hidden to such an extent as is the case in New York, Washington, Philadelphia and Chicago. It is thus the city which has the most to attract a great convention of teachers.

The meetings of the National Educational Association are, in a large measure, an excursion or picnic, the interest of the city and the journey counting for more than the program. There are few or no sessions in the afternoon, not more than half the members attend the sectional meetings in the morning, and not more than one tenth the general evening sessions after the first day. This is quite as it should be, for the teachers from all over the country gain much from travel, sightseeing and social exchange, whereas the programs do a good deal of threshing over of old straw. It is, however, a great stimulus for these teachers to see and hear their leaders; and it was worth going to Boston to listen to the president of the association, President Eliot, of Harvard University, who is without peer as a presiding officer and speaker.

In his presidential address entitled 'The New Definition of the Cultivated Man,' Dr. Eliot—who, it may be called to mind, was a professor of chemistry before he became the greatest college president and educational leader of the country—laid stress on the fact that the scientific method has been the means of the wonderful widening of the intellect that has occurred during the past hundred years and is as necessary for culture as are the humanities; but no special language or literature, such as Latin or Greek, is now essential, English having become incomparably the most extensive and various and the noblest of literatures. After referring to a work of Zola's, Dr. Eliot said:

> Contrast this kind of constructive imagination with the kind which conceived the great wells sunk in the solid rock below Niagara that contain the turbines that drive the dynamos, that generate the electric force that turns thousands of wheels and lights thousands of lamps over hundreds of square miles of adjoining territory; or with the kind which conceives the sending of human thoughts across three thousand miles of stormy sea instantaneously on nothing more substantial than ethereal waves. There is going to be room in the hearts of twentieth century men for a high admiration of these kinds of imagination, as well as for that of the poet, artist or dramatist. It is one lesson of the nineteenth century, then, that in every field of human knowledge the constructive imagination finds play—in literature, in history, in theology, in anthropology and in the whole field of physical and biological research. That great century has taught us that, on the whole, the scientific imagination is quite as productive for human service as the

literary or poetic imagination. The imagination of Darwin or Pasteur, for example, is as high and productive a form of imagination as that of Dante, of Goethe, or even of Shakespeare, if we regard the human uses which result from the exercise of imaginative powers, and mean by human uses not meat and drink, clothes and shelter, but the satisfaction of mental and spiritual needs.

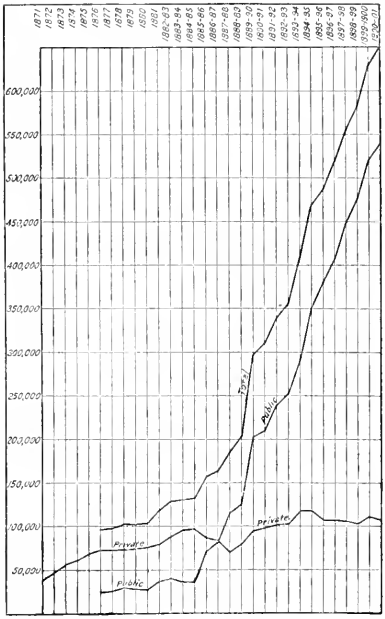
There were some three hundred speakers announced on the official program, a few of whom addressed the general evening sessions, while the others took part in the departmental sections for elementary, secondary and higher education, science, normal schools, school administration, physical education, defective children, Indian education, business, art, music, libraries, child study and kindergarten. The discussion of the teaching of science should be of especial interest to the readers of this journal, but this is never noteworthy at the meetings of the association, there being very few men of science in attendance. It is unfortunate that this is the case.

PRESIDENT CHARLES W. ELIOT.

as it is of the utmost importance for scientific leaders to familiarize themselves with the teaching of science in the public schools. We ought to know, for example, why the number of high school students studying physics decreased during the past ten years from twenty-four to eighteen per cent. while the number studying Latin increased from forty to fifty per cent.

THE PROBLEM OF THE COLLEGE.

The most interesting discussion at the meeting of the National Educational Association was one on the length of the baccalaureate course and the preparation for the professional schools, in which Presidents Eliot, Harper and Butler and Deans West and Hering were the official speakers. It is a most important question. There are now somewhat over 100,000 students in our colleges, universities and technical schools, and somewhat over 50,000 students in our professional schools of theology, law and medicine. In 1901, the last year for which the records have been published by the Bureau of Education, there were graduated from the colleges and technical schools 16,513 students, of whom 11,463 were men and 5,050 were women. Fifty different kinds of degrees were given to these graduates; but the classification of the commissioner of education is apparently faulty in attributing students of engineering to the colleges rather than to the professional schools. The number of regular academic bachelor degrees conferred was as follows: A.B., 7,943; B.S., 3,023; Ph.B., 1,112; B.L., 716. Of higher degrees the numbers were A.M., 1,280; M.S., 192; Ph.M., 22; M.L., 12; Ph.D., 343; Sc.D., 5. From the professional schools there were: graduates in theology, 1,585; in law, 3,366; in medicine, 5,472; in dentistry, 2,311; in pharmacy, 1,373; in veterinary medicine, 109. The number of students in theology has remained practically stationary since 1890; medical students have increased 73 per cent., and students of law to the remarkable extent of 202 per cent. In this period the men attending the colleges have increased 68 per cent. and the women 159 per cent., a relation which some will find gratifying and others will regard as ominous. The large figures do not represent the real increase in students, as the high school is now doing in large measure what was formerly done by the college. The increase in the number of high



Number of Students in Public and Private Secondary Schools.

school students, as shown in the accompanying chart, is truly remarkable. Worthy of note is also the fact that the increase is entirely a matter of the public secondary schools.

Of the 650,000 students in high, normal and preparatory schools, the 100,000 in colleges and the 50,000 in professional schools, the college students appear to cause the most difficulty to educators. The relation of the college to the high school, on the

one hand, and to the professional school, on the other, is a problem that may ultimately be solved by the elimination of the old-fashioned college. The better high schools overlap the first two years of the weaker colleges, and the last two years of the college are often given in part to specialized or professional studies. Only one medical student in twelve holds a bachelor's degree. Our college is regarded as a distinctly American institution and is venerated as such. When there were but few high schools and when professional schools were private ventures, the college was the chief factor in education and culture. It is, however, now struggling for its existence, and has become so hybridized and diversified that there is no typical college.

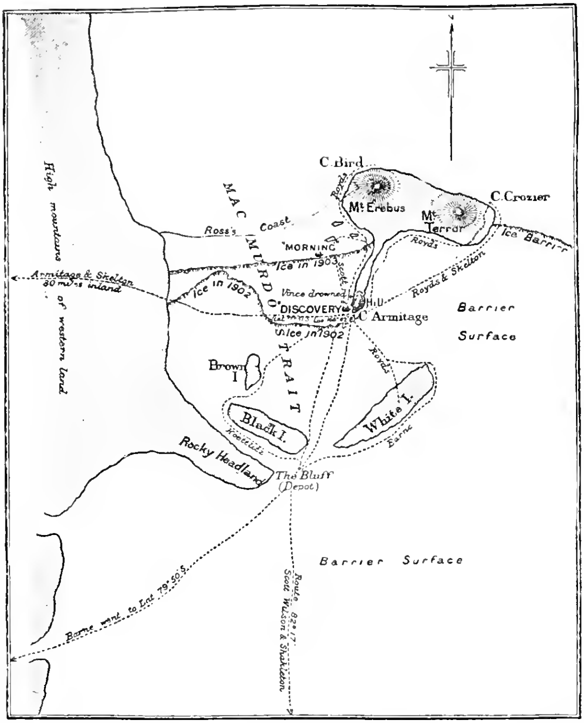
The differences of opinion among the college administrators who took part in the discussion at Boston were extreme. President Eliot has consistently urged a three-year college course, beginning at the age of eighteen, consisting of elective studies and required for the professional schools. Dean West said that three years might be quite long enough for electives, but that we should have a four-year course composed of 'disciplinary' studies. President Harper also favors four years, but allows a sliding scale. President Butler prefers a two-year course for students preparing for the professions, beginning at the age of sixteen or seventeen. All the college officers who spoke at Boston agree, however, that the college course must be prerequisite to the professional schools, at least to the better ones. None of them seemed to regard it as possible that the distinction between 'cultural' and useful studies is artificial. Certainly none of them suggested that the student should be set free to do his work, and the baccalaureate degree be given him on his twenty-first birthday.

THE BRITISH ANTARCTIC EXPEDITION.

Advices received in England and announced by the president of the Royal Geographical Society and others make it possible to form a reasonably correct estimate of the work accomplished by the British Antarctic Expedition and its present condition. The *Morning*, the relief ship under the command of Captain Colbeck, sighted the *Discovery* on January 23, but owing to the ice pack was not able to approach nearer to it than a distance of five miles. The *Morning*, having transferred the stores, left the ice on March 2, when there was already danger that she would become shut in. At this time it was hoped that the *Discovery* might be released from the ice, but this evidently proved impossible, as the ship would have reached New Zealand before this. We reproduce from the *Journal of the Royal Geographical Society* a sketch showing the position of the *Discovery*, the configuration of the land and the routes taken by the expeditions. It will be seen that the ice line was considerably further north in 1903 than in 1902, and unless it retreats in 1904, the *Discovery* must be abandoned. It is of course necessary under these circumstances to send a relief expedition again next year, and efforts are being made to collect money for this purpose. The government has been applied to for assistance, and the premier in the House of Commons recently, while implying that assistance would be granted, rather severely blamed the Royal Geographical Society and the Royal Society for not foreseeing this need.

The most dramatic result of the expedition was reaching the point furthest south, at latitude 82° 17′, from which land could be seen as far south as 83° 30′, with mountain ranges and peaks as high as 14,000 feet. The trip was made by Captain Scott, accompanied by Lieutenant Shackleton

and Dr. Wilson, who traveled nearly one thousand miles, drawing their sleds, after it had been necessary to kill the dogs owing to lack of food. Lieutenant soundings and deep-sea dredgings were made, and undoubtedly valuable zoological and botanical collections were obtained.



Sketch showing the Position of the *Discovery* in the Antarctic Regions.

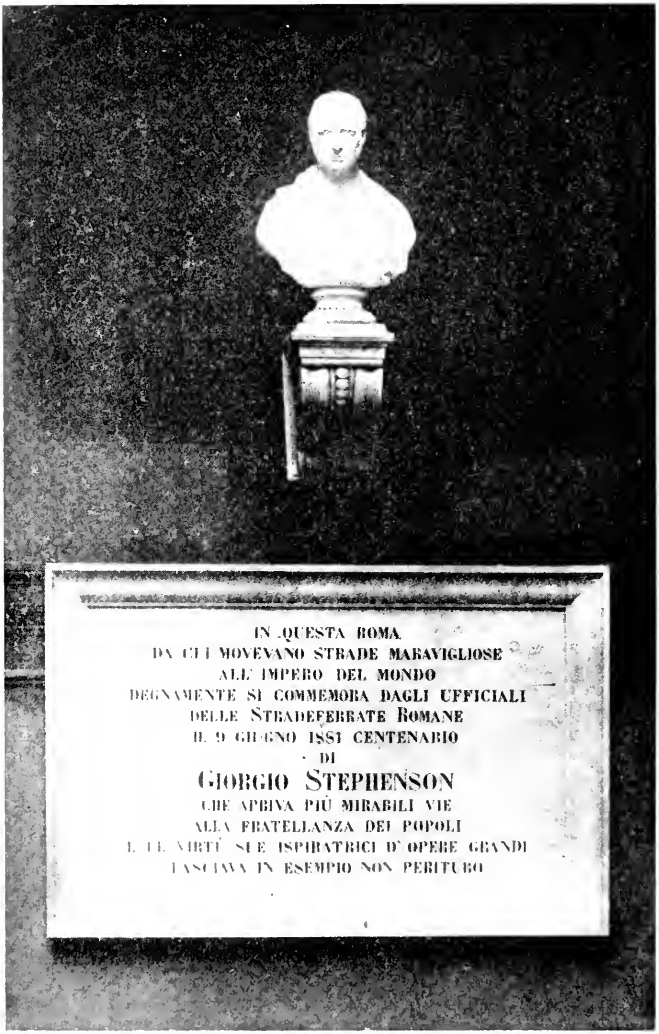
Shackleton, who became ill, returned on the *Morning*, and is about to publish an account of the expedition. Another expedition headed by Lieutenants Armitage and Skelton went westward, climbing a glacier 9,000 feet high, the ice extending far inland. Other geographical results of interest were the discovery that Mts. Erebus and Terror are on a small island and that MacMurdo Bay is not a bay but a strait. The remaining scientific work of the expedition has not been reported on very fully. Magnetic work was carried on continuously, some 400 magnetograms having been taken; a seismograph was also working regularly;

THE SO-CALLED MOSQUITO DESTROYER.

The New York *Sun* of July 13 printed an article to the effect that the Public Health and Marine-Hospital Service had discovered a parasite which would destroy mosquitoes, and from the account it appears as if the service intended to breed these worms in order to use them as a practical means for combating the mosquito plague. As the proposition is one which will doubtless attract popular attention, it will be well to place the exact facts before our readers.

A comparison of the *Sun's* account with the publications of the service

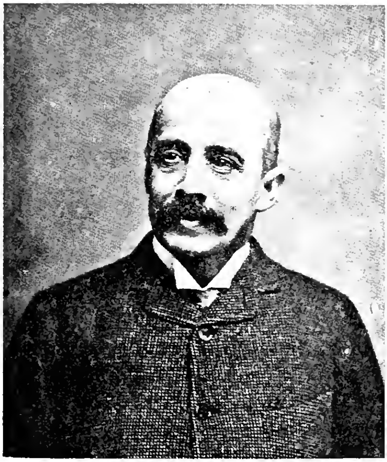
shows that the newspaper account is based directly upon an article by Dr. Stiles which is entitled 'A Parasitic Roundworm (*Agamomermis culicis*) in American Mosquitoes (*Culex sollicitans*),' and which appeared in 'Bulletin 13,' Hygienic Laboratory, of the service. In this article Dr. Stiles refers to several parasitic organisms which have been described from mosquitoes in different parts of the world and adds a new one to the list. This is a roundworm about half an inch long which lives in the abdominal cavity. He says: "At a time when mosquitoes are subjected to such careful study, because of the important relations they bear to public health, especially in connection with malaria, yellow fever, etc., it is of interest to determine what parasites



MEMORIAL TO GEORGE STEVENSON, RECENTLY ERECTED IN THE RAILWAY STATION AT ROME

naturally infest them. This determination has its practical as well as its scientific value, for it enables us to eliminate certain non-pathogenic parasitic organisms from the life cycle of pathogenic organisms, stages of which may be found in mosquitoes. It further has its direct practical bearing in that the parasites of mosquitoes may multiply to such an extent as to become important factors in killing the insects, or at least in rendering them less fertile."

He also refers to a similar *Agamomermis*, which he found in mosquitoes in Leipzig and which, according to Leuckart, seems to have an influence in decreasing the numbers of mosquitoes. Finally Dr. Stiles says: "These cases represent interesting instances in nature, where a pest is subject to other pests which tend to hold the former in check."



PAUL BELLONI DU CHAILLU, THE AFRICAN EXPLORER, WHO DIED ON APRIL 29, 1903.

We do not find in the article any suggestion that the Public Health Service is breeding these worms for practical purposes, as intimated by the *Sun*, in order to kill mosquitoes. In fact, it would take considerable study to determine whether such a plan would be practicable. If this parasite could be bred artificially in sufficient numbers it is by no means an impracticable proposition to utilize them to destroy mosquitoes in regions where the use of kerosene is difficult or impossible. We do not, however, gather from the article the impression that the service proposes any such plan at present. In fact, we can see technical difficulties in the way which would make the method rather expensive, and it would, at most, be applicable only under certain conditions. We can not, therefore, hold out any great hope that *Agamomermis culicis*, which the New York *Sun* has named the 'mosquito destroyer,' presents to us at present a substitute for kerosene and proper drainage. But we share the view expressed in the original article that this represents 'a case of parasitism of considerable interest' and that parasites of mosquitoes, like parasites of other animals, 'may multiply to such an extent as to become important factors in killing the insects, or at least in rendering them less fertile.'

RADIUM IN ENGLAND.

THAT marvelous substance radium, some account of which was published in the POPULAR SCIENCE MONTHLY for July, 1900, and June, 1903, still attracts the attention of both men of science and laymen throughout intellectual nations. In London recently the luminescent property of the rays issuing from the element was shown to King Edward and Queen Alexandra, on the occasion of their visit to the London Hospital, and the penetrating power of the rays was also demonstrated by the following: A pile of six pennies was placed over a small piece of radium and the light emitted was visible through the coins.

At the Museum of Natural History, London, the director has arranged a little exhibition with a view to giving the public an opportunity of seeing the material and some of its interesting properties. Its source is shown in

specimens of uraninite, or pitchblende, one from mines in Cornwall, and the other from Bohemia; as is well known to readers of the MONTHLY, only a few decigrams of radium can be separated from a ton of the mineral, and the isolation of the element is difficult, owing to its chemical affinities with the metals of the alkaline earths (barium, strontium and calcium). In contrast with the velvety black, massive pitchblende, are a few decigrams of pure radium bromide, a white salt resembling exteriorly common salt. Near by is a salt of barium, the crystals of which are rendered luminous when exposed to the emanations from a radium compound, even when a pile of copper coins, or a piece of marble more than one inch in thickness, is placed between them. The labels on these specimens duly explain that these emanations also act in the dark on photographic plates, and make the air traversed by them conductive of electricity.

The exhibition also includes the following: A box blackened inside and mounted on a stand, the whole resembling somewhat a large photographic camera, especially since the open end of the box is screened with black velvet that might be mistaken for a focusing cloth. On raising this screen the visitor sees at the farther end in letters of light, the word R-A-D-I-U-M. This word has been painted with radium bromide on hexagonal sulphide of zinc, which becomes luminous when brought near a compound of radium. Thus the emission of light by the new element is demonstrated as effectively, though not so strikingly as by Sir William Crookes in his experiments at the conversazione of the Royal Society, when the scintillations of radium were rendered visible by means of a blende screen and intensified by the use of a lens of moderate magnifying power. Residents of London, and visitors to that metropolis, will enjoy forming practical acquaintance with radium and with some of its extraordinary properties that may be envied by citizens of America.

THE FRANKLIN PAPERS IN THE LIBRARY OF THE AMERICAN PHILOSOPHICAL SOCIETY.

AT the meeting of the American Philosophical Society last spring, Mr. J. G. Rosengarten gave an account of some seventy large folio volumes of Franklin's papers, preserved in the archives of the society. Franklin left all his papers to his grandson, William Temple Franklin, who, after a long interval, published in London and in Philadelphia six volumes of Franklin's works. Of course, this represented but a small part of his papers. Those used in the preparation of Temple Franklin's edition are now the property of the United States, which has never yet printed a calendar of them. Temple Franklin selected from his grandfather's papers those that he thought suitable for publication, and left the rest of them in charge of his friend, Charles Fox, to whom he bequeathed them, and Charles Fox, in turn, after a long lapse of years, presented them to the American Philosophical Society, in whose custody they have remained ever since.

They have been roughly classified, and are bound in a rude and careless way. Under the present efficient librarian, Dr. Hays, a calendar is being made as fast as the limited means at his disposal will permit, and, when it is completed, it is hoped that it will be printed as a useful guide to the miscellaneous matter collected here. Sparks, Hale, Ford, Parton, Fisher and others who have written about Franklin have used them, but even the most industrious student may well be appalled at the labor required to master all the contents of these bulky volumes representing Franklin's long and many-sided activity.

He kept copies of most of his own letters and the originals addressed to him, often indorsing on them the heads

of his replies. These volumes contain papers from 1735 to 1790—the first forty-four volumes, letters to him; the forty-fifth, copies of his own letters; the forty-sixth, his correspondence with his wife; the forty-seventh and forty-eighth, his own letters from 1720 to 1791; the forty-ninth, his scientific and political papers; the fiftieth, his other writings—notably his Bagatelles, those short essays which had such a vogue, and which are still read; the fifty-first, poetry and verse, his own and that of others, no doubt selected by him for use in his publications; the fifty-second, the Georgia papers—he was agent for that colony; and the remaining twenty volumes, all the multifarious correspondence, other than official, mostly during his long stay in France, his various public offices at home and abroad, his enormous correspondence about appointments from men of all nationalities, who wanted to come to America under his patronage to fight, to settle, to teach, to introduce their inventions for every imaginable and unimaginable purpose.

Both in England and France he kept all notices of meetings, such as those of the Royal Society, and other scientific bodies of which he was a member, invitations, visiting cards, notes, business cards, etc., and at home he kept copies of wills, deeds, powers of attorney, bonds, agreements, bills and drafts, checks, bills of lading, public accounts and even certified copies of acts of congress and account books. It is to be hoped that the preparation and publication of the calendar showing the contents of this rich mass of materials may be completed at no distant day, certainly by the two hundredth anniversary of the birth of Franklin.

THE EDUCATION OF ENGINEERS.

At a recent meeting of the British Institution of Mechanical Engineers, Professor W. E. Dalby read a paper on 'The Education of Engineers in America, Germany and Switzerland.' According to the report in the London *Times*, the author pointed out that with scientific progress, changing methods of manufacture and the advent of electricity, there has been scarcely any change in the recognized methods of training engineers. At the present time, however, there is no difficulty in obtaining scientific instruction of a high character, and a training in workshop practise second to none can be secured in the factories of this country. The weak point is the want of cooperation between the workshops and the colleges. The author proceeded to give details of the course of instruction followed at the Massachusetts Institute of Technology, Boston, U. S. A.; at Sibley College, Cornell University; at the Berlin Technical High School, and at the Swiss Federal Polytechnic School at Zurich. There is an essential difference in the methods of training in America and Germany.

In America the course of instruction is very exactly laid down; in Germany no student is compelled to take any special course, though, for his convenience, definite courses are laid down in the school calendar. At Zurich the course is partly prescribed and partly selected. The American course may be taken as 3,000 hours, distributed over four years; the continental course is 4,000 hours, distributed over three years, independently of laboratory work. The fourth year is not included, as it is cut up by examination work. In America a large proportion of the time is devoted to workshop practise; in Germany and Switzerland no time at all is thus occupied. The American courses are more practical in character and devote a large proportion of the course to the teaching of handicraft skill. In America a student finds himself with a degree or diploma at the age of twenty-one. Employers take him without premium and

pay a wage sufficient for maintenance straightway, recognizing that his knowledge places him in a different position to ordinary apprentices. In this way they get highly-trained men into their works, and by their own observation soon discover whether the youth possesses, in addition to intellectual acuteness, the qualities which go to make a successful business man or a good organizer, and recruit their staff accordingly. The author suggested the question whether the British method of training was better or worse; whether the methods could be improved in the light of what was being done abroad. Most people, he said, would consider the methods of Charlottenburg and Zurich too academical; whilst many, though admiring the American system of workshop instruction, think it better it should be obtained under the practical conditions of actual work. A youth who is to become a leader in the future needs to know the habits and thoughts of the men. One thing the author considered certain—the American, German or Swiss student starts his college course with a far better education on which to build.

SCIENTIFIC ITEMS.

Dr. Carl Gegenbauer, the eminent anatomist, since 1863 professor at Heidelberg, died on June 15, at the age of seventy-seven years.—Dr. A. A. Common, F.R.S., known for his important researches in astronomy, especially in connection with reflecting telescopes, died on June 2, at the age of sixty-two years.

A committee of eminent chemists has been formed to erect a monument at Heidelberg in memory of Robert Bunsen. It is intended that the contributions shall be international; they may be sent to the treasurer, Herr A. Rodrian, Heidelberg.

The park commissioners of Chicago have approved the transfer of the Field Columbian Museum from Jackson Park to Grant Park, which is on the lake front in the center of the city. It is understood that Mr. Marshall Field has agreed to give $5,000,000 for the construction and endowment of the museum.—It is said that the trustees of the Rush Medical College, the medical department of the University of Chicago, have collected $1,000,000 for the institution, and that this assures a gift of $6,000,000 to the school by Mr. John D. Rockefeller.

THE POPULAR SCIENCE MONTHLY.

SEPTEMBER, 1903.

PALM AND SOLE IMPRESSIONS AND THEIR USE FOR PURPOSES OF PERSONAL IDENTIFICATION.

By Professor HARRIS HAWTHORNE WILDER,

SMITH COLLEGE.

IN a former number of this magazine (November, 1902) I gave a brief account of the epidermic ridges upon the human palmar and plantar surfaces, and emphasized their great individual difference and their applicability for use in the identification of individuals, living or dead. In the present article I shall endeavor to set forth a simple method by means of which these individual records may be formulated and classified and thus be rendered serviceable as a practical system of personal identification.

Aside from the use of photographs and the more obvious descriptive methods, which include such attributes as height, weight, color of eyes and hair, moles, birth and tattoo marks, etc., there are now in use two distinct scientific systems of identification, that of M. Alphonse Bertillon, based upon bodily measurements, and that of Mr. Francis Galton, based upon the epidermic ridges of the finger tips.

These two systems are absolutely distinct from one another, although, judging from frequent newspaper notices, they are popularly confused, with a tendency to ascribe both to Bertillon, in the same way that electrical inventions are popularly associated with the name of Edison, or theories of evolution with that of Darwin. Indeed, there seems to be a common disposition in America to ascribe the idea of the use of 'thumb-marks' to Mark Twain, who in his 'Puddenhead Wilson' has undoubtedly done much to call the public attention to the epidermic ridges of that very restricted area, although, as a consequence of the story, one continually meets with the notion that the epidermic pattern

of the ball of the thumb (usually considered to be the right one alone) is individual and distinctive, while those of the remaining fingers, or the similar markings of the palm are of no importance.

It is of interest also to note that, owing to the common belief in palmistry, whereby divination is performed by means of the chance wrinkles caused by the motion of the fingers, these useless features have assumed so great importance that the far more interesting ridges appear to be usually ignored or even overlooked entirely, and as for the ridges of the sole of the foot or the balls of the toes, their very existence appears to be generally unknown.

Since there seems to be so much popular misinformation upon the subject of systems of identification, it may not be superfluous to begin the present discussion with a brief description of each of the two systems mentioned above, after which will be presented the claims of the system based upon palms and soles.

I. *The Bertillon system.*

The first scientific method for classifying humanity by data furnished by individual bodily peculiarities, or at least the first that became widely adopted, was that devised by M. Alphonse Bertillon, who in 1880 founded his celebrated system of identification by means of bodily measurements, 'Identification anthropométrique.' In this he applies the principles of anthropometrics, employed hitherto mainly as ethnological criteria or for use in physical culture, to the identification of individuals, using for that purpose only those measurements which depend on skeletal parts, and which are, therefore, practically unchanging after adult life is reached. The measurements selected to form the basis of his system are as follows:

I. Measurements based upon the entire body. [*Mesures relevées sur l'ensemble du corps.*]
- Standing height. [*Taille—hauteur de l'homme debout.*]
- Arm reach. [*Envergure des bras.*]
- Sitting height. [*Buste—Hauteur de l'homme assis.*]

II. Measurements based upon the head. [*Mesures relevées sur la tête.*]
- Length of head. [*Longueur da la tête.*]
- Breadth of head. [*Largueur de la tête.*]
- Length of right ear. [*Longueur de l'oreille droite.*]
- Breadth of right ear. [*Largueur de l'oreille droite.*]

III. Measurements based upon the extremities. [*Mesures relevées sur les membres.*]
- Length of left foot. [*Longueur du pied gauche.*]
- Length of left middle finger. [*Longueur du doigt médius gauche.*]
- Length of left little finger. [*Longueur de l'auriculaire gauche.*]
- Length of left cubitus. [*Longueur de la coudée gauche.*]
  i. e., elbow to tip of extended middle finger.

Each of these eleven measurements is subdivided into three groups, small, medium and large [*petit, moyen, grand*]; in accordance with

definite though arbitrary limits, themselves the result of much experience in measurements, and designed to divide any average set of measurements into three approximately equal divisions, rather than to divide equally the range of millimeters between the extremes of a given measurement. Thus, to quote an example furnished, "the numerical limits of the 'medium' head-length as used at the Prefecture of Police in Paris include an interval of but 6 millimeters (185–190), while those included under 'large' extend from 191 mm. to the greatest dimensions possible, an extent of more than three centimeters."*

Now if we were to conceive of each one of these eleven measurements as varying independently of one another and as being divided into three subdivisions, the number of possible subdivisions under which individual anthropometric records could be filed would reach the large number of 3 to the 11th power, or 177,147, but in practical use M. Bertillon employs for purposes of identification only a few of these measurements, which he gives in the work just quoted, together with an hypothetical application, as follows:

He supposes the case of 90,000 sets of measurements, a number approximately corresponding to that of the adult male prisoners recorded in the Paris prisons up to 1893. Of these the first classification is made by means of the *length of head*, and as the subdivisions, small, medium and large, are fixed with reference to equality of division, approximately 30,000 of these records will be placed in each.

Each of these subdivisions is now divided again into three parts, in accordance with the *breadth of head,* a division which leaves approximately 10,000 in each of the nine compartments, *i. e.,* 10,000 individuals whose head length and head breadth fall into the same categories. The third division, which reduces the number of records in each of 27 compartments to about 3,300, is based upon the *length of the left middle finger,* and the fourth, resulting in 1,100 in each of the 81 compartments, is based upon the *length of the left foot.* The *length of the cubitus* then follows, which increases the number of compartments to 243 ($=3^5$) and the number of individual cases in a compartment to less than 400. By the addition of the *standing height,* the number of compartments is increased to 729 ($=3^6$) and that of the cases in each compartment to approximately 130, and these numbers become respectively 2187 ($=3^7$) and 42 by the use of measurements taken from the *left little finger.* These are finally reduced to small sets of a dozen records each by such criteria as the *color of the eye* and the *length of the right ear,* after which this small number may be carefully compared for individual measurements.

With some modifications the above system is in official use in most of the civilized countries of the world, including England, Russia,

* Bertillon, A. 'Instructions Signalétiques,' 1893. Introduction.

Belgium, Switzerland, the United States and the majority of the South American republics, but in at least some of these cases the governmental acceptance of the system does not mean an extensive practical use, a condition of affairs especially true in the United States, where the governmental acceptance means merely an official sanction and where each state, or even each municipality, may employ its own methods of recording and registering criminals, quite independently of its neighbors. In this country the main reliance is placed upon photographs and descriptions, sent to various police headquarters in the form of little handbills, and although one sees occasionally among the descriptive part of these a set of Bertillon measurements (without further designations), it is very doubtful if in cities of moderate size the police authorities have any definite idea of their significance, or possess the necessary instruments for obtaining these measurements and thus verifying the data furnished. In England the Bertillon system is extensively employed, although in a somewhat modified form, to which is appended, at present as a supplementary system, that of Galton, to be described below. On October 21, 1893, a departmental committee was appointed by the home secretary, the Hon. H. H. Asquith, to inquire into the various methods of identification of criminals, and an official report was presented by them on February 12, 1894, and published as a Bluebook (C. 7263). The recommendations embodied in this report, and adopted in full by the English government, were as follows (paraphrased):

I. To photograph criminals as at present, the photographs to consist of both a front and profile view, taken on separate negatives, and not by means of a mirror, as heretofore.

II. To employ the first five of the Bertillon measurements, as follows, expressed in millimeters:

1. Length of head.
2. Breadth of head.
3. Length of left middle finger.
4. Length of left forearm.
5. Length of left foot.

III. To take the finger prints by Mr. Galton's method.

IV. To add a brief description including the height in feet and inches, color of hair, eyes and complexion and distinctive marks, the latter in a fixed order, beginning with the head, then the hands and arms, then the body, and lastly the legs and feet.

With regard to that portion of the recommendation which concerns the Bertillon system the committee gave its unqualified approval to the use of the first five categories as given above, but felt that the further subdivisions (height, length of little finger and color of eyes) were rather unsatisfactory. As stated in the report:

The length of the little finger is closely correlated with the length of the middle finger; in most cases where the one is long, the other is long also. The height again is a very unsatisfactory measurement; it is subject to varia-

tion in the same person, and it may be attended by trickery on the part of the person measured. By the Metropolitan Police a margin for error of two inches in each direction is allowed in classifying cases by height. Even with the greater accuracy of the French measurement a considerable margin has to be given. The accurate description of the color of the eye is still more difficult. The seven colors taken by M. Bertillon can be discriminated only by persons having much practical experience, and even then many doubtful and transitional cases must occur.

For the 'primary classification,' that based on the first five Bertillon measurements, a complete outfit, such as would be necessary at an important registration station, would consist of 243 drawers, corresponding to the 5th power of 3, the number of possibilities involved.

The arrangement of this index register will be the same as M. Bertillon's, a cabinet of drawers first divided vertically into three divisions according to length of head, and horizontally according to width of head. The nine sections thus formed will be divided vertically according to length of finger and horizontally according to length of forearm, and again vertically according to length of foot. There will be 243 drawers, each containing one class of cards. The figures which are to determine the 'long,' 'medium' and 'short' of the several classes might be borrowed in the first instance from M. Bertillon, but in that case on account of racial differences they would have ultimately to be altered in order to keep the classes equal in size. It would be best, therefore, that the measurements taken in this country by Mr. Galton and by the Anthropological Institute should be utilized and correct figures for England fixed from the outset.

The above quotation from the English report is given in full mainly for the purpose of showing the great disadvantage to the entire system, which results from racial differences in bodily proportions, a fact which will necessitate either one of two alternatives, both bad; that of using special figures for each country or of having very unequal subdivisions in certain cases. This is a decided barrier to the internationalizing of the system and must necessarily be reckoned as a serious defect.

Without meaning to seem ungracious to a system the advantage of which over all previous methods has been universally recognized, and one the scientific principles of which reflect so much credit upon the deviser, it may be well, in closing this brief account, to enumerate the defects of the Bertillon system, some of which are, indeed, incident to any system which human ingenuity can devise, and the most of which have been foreseen, acknowledged and corrected so far as possible by M. Bertillon himself.

1. The limitation of the system to the period of adult life.

2. The necessary disparities between the same measurements taken at different times by different mensurators, or indeed by the same one (percentage of error).

3. For the purpose of an equal classification, the necessity of assigning independent limits to the records kept by each nation.

4. The greater amount of time consumed in making a set of meas-

urements and in recording and classifying the same, as compared with the printing and reading required by either the Galton system or by the one advocated in the present paper. A careful test of this has not yet been made, but when we consider the number of single acts involved in the making of the records required by each system, the conclusion is obvious. In identifying an individual by means of a previous record, the Bertillon system demands a complete remeasurement, while by the palm and sole system a mere glance at a single palm is often sufficient to establish the identity or the reverse. Ordinarily the difference of time may not be great, but in the stress of modern competition a slight disadvantage in this particular may be regarded as a relative defect.

5. A more serious defect, which is also brought out by comparison, is that the certainty of a Bertillon determination is not absolute, while that of a system which involves either the finger tips or any other considerable portion of the epidermic ridges of hand or foot is beyond question. This has been thoroughly proved statistically by Galton and morphologically and embryologically by a series of recent investigations in my laboratory.* The proof afforded by the study of duplicate or 'identical' twins, where the resemblance, though greater than it can be in any other two persons, is still not absolute, affords farther evidence of the same.† Galton says that a proved identity of finger prints "far transcends in trustworthiness any other evidence from any number of ordinary anthropometric data. *By itself it is amply sufficient to convict.* Bertillonage (*i. e.*, the system of Bertillon) can rarely supply more than grounds for very strong suspicion; the method of finger prints affords certainty."‡

Although in the original system devised by him Bertillon confined his attention mainly to anthropometric measurements and rejected all use of epidermic marking of hand or foot as impracticable§ in his capacity as chief of the Bureau of Identification and with the evident

* A report of these investigations will shortly be published. See note, p. 396.

† See *Am. Journal of Anat.*, Vol. 1, No. 4, November, 1902.

‡ 'Finger Prints,' Macmillan, 1892, pp. 167–168.

§ "Ainsi la solution du problème de l'identification judiciaire consistait moins dans la recherche de nouveaux éléments caracteristiques de l'individualité que dans la decouverte d'un moyen de classification. Certes, je ne conteste pas, pour ne parler que du procédé chinois, que les arabesques filigranées que presente l'epiderme de la face anterieure du pouce ne soient à la fois fixes chez le même sujet et extraordinairement variables d'un sujet à un autre; et que chaque individu ne possède là une espèce de sceau original et bien personnel. Malheureusement il est tout aussi indéniable, malgré les recherches ingenieuses poursuivies par M. Francis Galton, en Angleterre, que ces dessins ne presentent pas par eux-même des éléments de variabilité assez tranchés pour servir de base à un repertoire de plusieurs centaines de mille cas." Bertillon. 'Instructions Signalétiques,' 1893, Introduction.

desire of bringing his work to the highest degree of efficiency, he has recently adopted a part of Galton's system, and places the impressions of certain of the finger-tips upon his identification-cards.

Unfortunately, I can not ascertain the exact date at which this adoption of Galton's system was made, but upon a fac-simile card, shown in a recent popular article on Bertillon's system (*Leslie's Weekly*, April 16, 1903), which is dated August, 1901, spaces appear below the words 'Pouce, Index, Medius, Annulaire' and are plainly intended for the reception of the corresponding finger-prints. Within a few weeks of the present writing there have appeared in various newspapers (*e. g., Boston Herald*) accounts of the employment in the State Prison at Auburn, N. Y., of imprints both of the fingers and of the entire palm, but I am unable to ascertain anything definite concerning the manner in which these prints are to be used. Mr. John N. Ross, the chief of the Bertillon department of the above-named prison, has kindly given me what information he can concerning the matter, but writes that it is 'an entirely new departure' and that 'directions as to its application have not yet been received by the Bertillon operators of the different penal institutions' (June 29, 1903). I am thus unable to say whether M. Bertillon has in mind the incorporation of any part of my system with those of himself and Mr. Galton, but I have furnished him with reprints of my two previous papers on the subject and have sent him also numerous manuscript notes and sample prints, which together present the essential points of the system as given in this paper.*

Should this system of mine be found of value and permanently incorporated with the others, the 'Bertillon' system known in actual practice will be, like most other inventions of real value, a composite resulting from the independent investigations of several individuals working from different standpoints, and should be carefully distinguished from the real Bertillon system as described by him in his published work, and outlined above.

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* M. Bertillon's reply to the sending of my first paper is as follows:

PARIS, le 12 Janvier 1903.

MONSIEUR,

J'ai pris grand interêt à la lecture de votre étude sur les lignes papillaires du pied et de la main, et je vous prie de recevoir tous mes remerciments pour l'obligeance que vous avez eue à m'adresser cette publication.

Conformement à votre désir, je vous transmets un examplaire de l'Introduction de l'ouvrage qui j'ai fait paraître en 1893 sous le titre de "Instructions Signalétiques." l'editeur en est Mon. Durand, Rue Oberkampf No. 80 à Paris.

Veuillez agrier, Monsieur, l'expression de mes sentiments les plus distingués.

Le Chef du Service de l'Identification

A. BERTILLON.

Monsieur H. Wilder à Northampton.

II. *The Galton system.*

In the popular mind, as attested by numerous works of fiction and by newspaper articles, the main use of the patterns of the finger tips is to aid a detective in identifying a criminal by means of the marks which his fingers have left upon the objects which he had handled; but, as a matter of fact, although such a proceeding is certainly possible, Galton seems never to have suggested such sensational aid to detective work. Both the Bertillon and the Galton systems are rather methods of describing and registering a man, whether a criminal or not, by certain physical peculiarities and in such a way that he or his body may be identified at any future time; and both involve two procedures, (1) that of taking certain individual records, and (2) that of classifying and arranging them so that they may be easily found when occasion requires. The Galton system is based upon imprints of the epidermic patterns found upon the balls of the thumbs and fingers, and Mr. Galton, although by no means the first to employ such means for the identification of individuals, is the first to attempt a careful and scientific system by which these data may be described, registered and classified.

The use of such prints has been sporadically employed in both ancient and modern times, and seems to have long been in use among the Chinese, but data concerning the official workings of this vast and ancient empire are difficult of access to Europeans, and it is likely, as in so many other claims, that the facts when found will be disappointing when compared with the reports concerning them. Galton himself was first led to the study of finger prints by his friend Sir William Herschel* who, when 'Collector' or chief administrator of the Hooghly district in Bengal, added to the signatures of the natives upon all official documents the imprint of the index and middle fingers of their right hands, taken by means of the ink employed for his office stamp.

Galton, indeed, says of his friend that 'if the use of finger prints ever becomes of genuine importance, Sir William Herschel must be regarded as the first who devised a feasible method for regular use and afterwards officially adopted it,' but it must also be remembered by the one who writes the final history of this system that it was Galton who devised the method by which such prints could be described and classified, and thus become of practical value.

The Galton system of personal identification by means of finger prints rests upon two necessary principles, both of which have been established by him beyond refutation:—

I. The absolutely individual character of the markings.

II. Their permanence throughout life.

* In Indian Service 1853–1878.

The records employed are the printed impressions of the ten digits placed in a definite order upon a card, and the separate cards are placed on file by means of a classification wholly dependent upon the individual patterns.

Of those latter there are three types, the *arch*, the *loop* and the *whorl*, designated in descriptive formulæ by their initial letters, A, L and W (hence the name of 'the *alw* system' by which Galton has designated it). Of these the loop, which may turn to either the radial or the ulnar side of the hand, is for some purposes farther subdivided into *radial* and *ulnar* loops designated respectively as R and U. The patterns are definite in their nature; transitions between them are of rare occurrence and these are nearly always referable to one type or the other. This system of 'ALW,' with the occasional subdivisions of the R and U, forms what Galton designates the *'Primary Classification,'* and the finger tip records of any number of individuals are arranged in accordance with a preconceived order. Although he has made several experiments in this, in his final method (1895) the sets are first arranged in four divisions (ARUW) in accordance with the type of pattern found upon the *right index finger*. This is followed by (small) letters designating the patterns upon the middle and ring fingers of the same hand, using l instead of r and u for all looped patterns. This will be seen to subdivide each of the first four divisions into 9 or will divide an entire set into 36, as follows:

Aaa	Raa	Uaa	Waa
Aal	Ral	Ual	Wal
Aaw	Raw	Uaw	Waw
Ala	Rla	Ula	Wla
All	Rll	Ull	Wll
Alw	Rlw	Ulw	Wlw
Awa	Rwa	Uwa	Wwa
Awl	Rwl	Uwl	Wwl
Aww	Rww	Uww	Www

If, now, the prints in each of these 36 divisions be farther subdivided in accordance with the same three fingers of the left hand, each subdivision consisting likewise of 36 compartments, the entire collection will be divided into 36^2 or 1,296. The thumb and little finger of the right hand which show 9 possible combinations, will subdivide each of the 1,296 compartments and, in like manner, the patterns of the thumb and little finger of the left hand will give another subdivision of 9, so that the number of possible compartments or subdivisions into which a set of prints may be arranged by means of this primary classification alone is $1{,}296 \times 9 \times 9$ or 104,976; and since the various combinations with a few exceptions occur with about the same frequency, the number of separate prints in a collection of five

hundred thousand which it would be necessary to look over carefully in comparing with a certain definite case would average about five.

The data necessary for this latter comparison are abundantly furnished by the details of the individual ridges, termed by Galton the 'minutiæ,' and the farther description and subdivision of the records by means of these he terms the '*Secondary classification.*' These and other useful details are appended to the formulæ given above by means of 'descriptive suffixes,' arbitrarily selected and described in a table, a copy of which must, of course, be always at hand, at least until it be thoroughly committed to memory by the clerk in charge of the records. The nature of these suffixes and of the details which they describe may be learned from the following examples, taken at random from Galton's table:

g. The core to the whorl is very large.
o. The core of the whorl is a detached ring.
x. Interpretation questionable; the pattern is peculiar.
† Scar left by a cut.

The implied suggestion of 'x' brings up a question which probably occurs to the reader at about this time, namely, whether a pattern is ever of a mixed type, or half way between two, thus giving a chance for a difference of interpretation and a consequent embarassment in finding the case from the formula. This certainly occurs occasionally, but Galton has well disposed of the difficulty by comparing it to the doubt experienced when consulting a city directory for a Scotch name beginning with 'Mac,' variously written, either in full or as Mc or M', and classed differently by various lexicographers. In both cases the investigator, failing to find what he desires in one place, looks in another, and neither here nor there is the difficulty a serious one.

Each finger tip record is placed on a card measuring 12 x 5 inches, and contains, when complete, rolled impressions of the ten digits, a set of 'dab' impressions of the four fingers of each hand (as duplicates for comparison) and, at the right hand upper corner, the formula. In Scotland Yard a folded paper is used instead of a card, and the arrangement of the prints differs somewhat from the above.

Concerning the practical adoption of the Galton system at present, it is hard to get details, but the recommendation of the English committee in 1894 has been referred to, and it seems that since that time the method has come into quite general use in England. It is of course impossible to devise a method which in every detail will be perfect from the start, and as Mr. Galton is continually at work upon his system, the improvements suggested both by him and by those practically engaged in the work can not fail to modify details until it is brought to the highest degree of efficiency.

III. *The palm and sole system.*

The method which it is the purpose of this paper to advocate and briefly explain is closely allied to that of Mr. Galton and is, in fact, *an extension of his system to the palmar and plantar surfaces, which are covered with the same sort of ridges as are the finger tips and in which the variation is greater and the details larger and more obvious.* A moment's inspection of a human hand and foot will show that the entire ventral surface of each, including that of the digits, is covered by a peculiar sort of skin, very different from that found elsewhere, and that along the sides of the palm and the digits, and just above the sole upon the foot, there are definite lines of separation between them and the normal skin, which in the hand corresponds in general position to the seam in a glove which unites the upper and under surfaces. This palmar and plantar skin differs from that of the rest of the body in many ways. It is absolutely hairless and at no time during embryonic life shows indication of either hairs or hair follicles. It consequently has no power of forming goose-flesh when chilled, although the back of the hand and the surface of the forearm, in the immediate vicinity of the palm, are favorite places for the display of this phenomenon. It is also very slightly, or not at all, pigmented as is readily seen by inspection of the palms and soles of a negro, and consequently does not tan or freckle, a distinction often made very obvious by a comparison of the back of the hand with the palm. The most obvious character, however, and the one which directly concerns both Galton's system and the one advocated here, is that of the small but distinct epidermic ridges, which cover the surfaces in question. These may be said to run in a general way parallel to one another and diagonally across the palm or sole, although in certain regions their direction is altered and at more or less definite places they form curiously disposed patterns, usually in the form of loops or spirals. With a moderate lens these ridges give the skin an appearance much like that of corduroy and there may be seen running along the middle of each ridge a row of minute indentations or pores, at about equal distance from one another, the orifices of the perspiratory glands. Running over and across these ridges in directions which bear no relation to them are the wrinkles or *rugæ*, more abundant in the hand than in the foot, and caused by the various motions of the digits and of the other movable parts of the member. Those seem at first especially obvious and interfere more or less with the study of the ridges, but a little practice will enable one to ignore them altogether. In printed impressions, which are used for purpose of study far more than are the actual surfaces, most of these are pressed out of existence while the remainder appear merely as narrow white streaks which do not affect the investigation (see Figs. 1 and 2).

These ridges and their peculiar disposal are an inheritance to us from our arboreal ancestors, and appear to be formed in the oldest primates by the coalescence of single units which arrange themselves in rows.* Whether or not this phylogenetic or racial stage is now passed through in each human embryo in accordance with the law of biogenesis has not as yet been shown, but it is certain that the ridges are seen fully formed and in their adult condition in a four-months' embryo, and that no change can afterwards take place in any detail.

As these surfaces are thus individually variant and as their condition is absolutely permanent throughout life, they offer the best possible criteria for a system of individual records, especially since they may be so easily recorded by means of printed impressions. All these points have been shown in a practical way by Mr. Galton, who has taken as the basis of his system the markings that cover the balls of the fingers, his 'finger-tips.' The present paper considers the remainder of the ridged surfaces and is thus seen to be *an extension of the Galtonian system to a new territory.* Whether ultimately the universal personal records, which will surely become a necessity in the near future, will be based upon a part or the whole of these surfaces is of no real moment, and it is with the idea of being of genuine assistance to Mr. Galton and without any attempt at rivalry that I offer in the following pages a method of recording identity by means of palms and soles.

M. Bertillon has said that there are not lacking individually variant parts of the body capable of use for purposes of identification, but that what is needed is some system of recording and classifying these differences, so that an individual case can be easily found. The system proposed here will, I think, fulfil this demand, and it will be seen that each human being is as well marked and labeled as though he were tattooed with an individual name and number, the interpretation and manner of cataloguing these devices being the only part not furnished by nature.

The method of printing a palm or sole is a very simple one, and although there are many little details which will occur to one who does much of this work, the essentials are the same in all cases. The outfit for printing consists of a tube of mimeograph ink, a rubber roller such as is used in amateur photography, and unruled paper of the required size. An inking surface is prepared by pinning a sheet of paper to a

* This and other morphological points of which I shall make use in this article are from an unpublished paper upon the morphology of the subject, by an associate in my department, Miss Inez L. Whipple. At my suggestion Miss Whipple has undertaken the comparison of the human conditions of palm and sole with those of the lower primates and other mammals, and has studied also the ontogenetic development of the parts in man and other forms. This work, which is of great value in the present connection, will be published in full in a short time.

board or table, placing upon it a little of the ink, and then rolling it down with the roller until the paper is coated with a uniform thin layer of ink. The best results are obtained when this is thin enough to appear of a dull green color rather than black, and the usual difficulty lies rather in using too much than too little ink. The hand or foot to be printed is then laid upon the inked surface, pressed a little, especially at the places which are naturally raised above the paper, and then removed and laid in the same way upon a clean sheet of paper, pressing the parts as in the first instance. Care must be taken not to slip the hand or foot sideways at any time, as this would blur the lines; a similar condition may be caused by too great pressure, and thus when the feet are taken the subject should be seated, allowing the foot to be manipulated by a second operator. The inking surface should be freshly rolled before each new impression, and when a number are taken at one time, a little ink must be occasionally added and rolled down. If mimeograph ink is not available, ordinary printer's ink will do almost as well, and both sorts may be readily removed from the skin by the use of a little turpentine or benzine, or even by soap and warm water.

After a collection of imprints has been made, the next procedure is the interpretation, that is, the tracing out of certain definite lines which mark the course of the ridges and define the patterns. As the palm presents simpler conditions than does the sole and is much the best for purposes of instruction, we will begin with a good average print like that given in Fig. 1, using a sharp-pointed pencil, and, when necessary, a reading glass of low power. At the base of each of the four fingers there will be seen a triangular area composed of transverse ridges, so intruded into the palm that it parts for some little distance the ridges which belong more definitely to the palm itself. These are the *four digital areas,* and at their apices are found points from which the ridges radiate in three directions, two bounding digital areas and one traversing more or less of the palm. These four points or triradii (equivalent to Galton's 'deltas') are the starting points of the system and may be termed the *four digital triradii,* numbered 1–4, beginning at the inner or thumb side. The lines bounding the digital areas are the *eight digital lines,* numbered from 1–8, and the four other lines which proceed from the triradii and cross the palm are the *four main lines.* These latter, designated by the letters A–D, are of primary importance and furnish by their course the *first* or *primary formulæ* by which the palms are classified. These lines are established by following the direction of the ridges to whatever point they may lead, and are best traced along a certain definite ridge, although, in places where a ridge that is being followed breaks or forks, the line should be continued by means of an adjacent ridge, or by taking the general direc-

tion indicated by several ridges. When the four main lines are traced, search should be made for a fifth triradius, the *carpal*, usually occurring in or near the middle of the palm just above the wrist, and its lines should be followed in the same way as in the other cases. The two short lines running downward to the wrist are the *carpal lines* and define the *carpal area*, and the longer one which curves about the base of the thumb is the *thenar*. A carpal triradius is not always present, but in some cases its place is taken by what may be termed a 'parting,' or a place where the ridges which run from the palm to the wrist divide

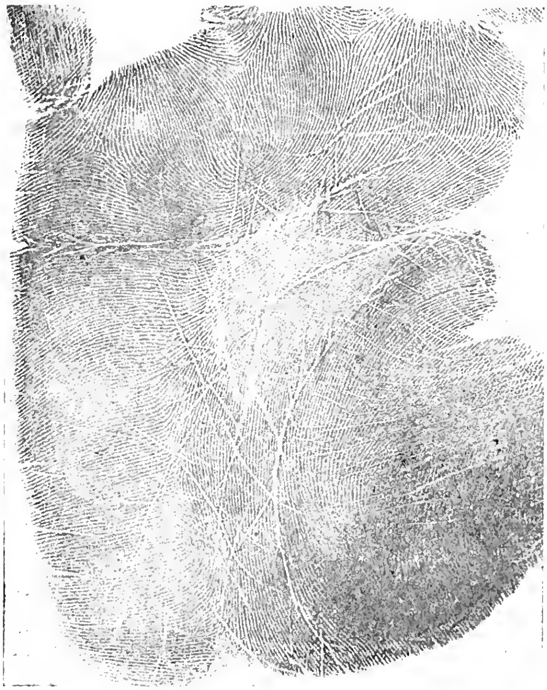

FIG. 1. PRINT OF LEFT PALM [COLLECTION NO. 206], NOT INTERPRETED.

into two groups, one half of which diverge toward the inner, while the other half diverge toward the outer side (see Fig. 4, *a* and *b*). When the interpretation is complete the palm impressions will resemble Fig. 2 (compare with Fig. 1).

If, now, similar impressions are made of a half dozen palms, a great individual difference in the course of the main lines will be at once apparent. They will curve in different directions, sustain various relations with regard to one another and *terminate at different points along the margin of the palm*. Although occasionally two palms will show the same general course of the main lines, there are, on the other hand, a large number of distinct cases, and this system may well serve

for a primary classification, or one which will divide individual records into a large number of sets, as described above in the case of the other two systems. In the former article in this magazine, I suggested this *by applying names to the various areas* marked off by the lines of interpretation, and proposed a set of descriptive formulæ based upon these areas to be used in designating the course of the lines. *I now wish to substitute for this a numerical system*, the *presentation of which in*

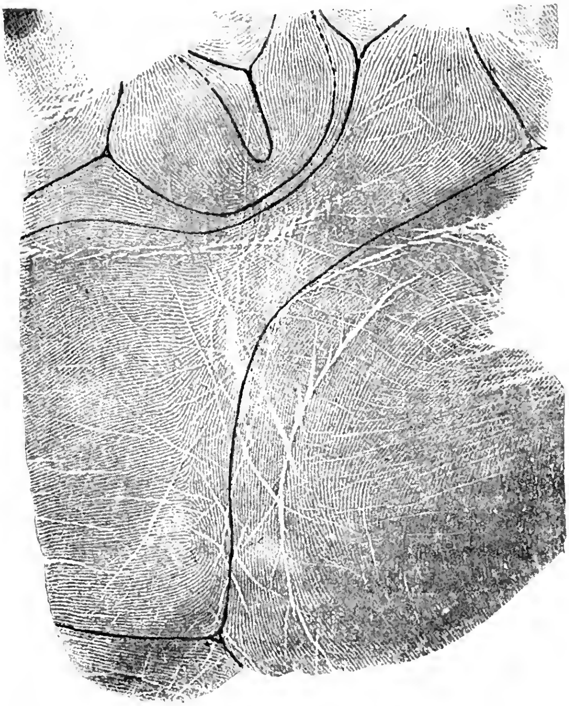

Fig. 2. Same as Fig. 1, covered by Lines of Interpretation. Note slight differences in the wrinkles in Figs. 1 and 2, although taken of the same palm at the same time.

the form of a key explains itself (Fig. 3). In this, each triradius and intermediate area is furnished with a number, the latter being designated by the odd, and the former by the even, numbers, and *the course of a given main line may be simply and accurately described by giving the number corresponding to the point at which it terminates.* To the extensive outer border where the use of a single number would be often indefinite, three numbers are assigned, 3, 4 and 5, although where complete accuracy is not needed the symbol 0 (for open) may be used, signifying merely that a given line passes out at some point along the free margin between the outer carpal line and the outer digital one of the little finger. Of these three numbers, 4 is used to designate a

pattern only, which occasionally occurs in this region, and which, when present, defines the territory below it as 3 and that above it as 5. A line entering it and returning along its lower side would be designated as 4/3 (Fig. 4, *d*), one emerging above as 4/5 and one that becomes involved in the pattern and does not emerge is simply 4.

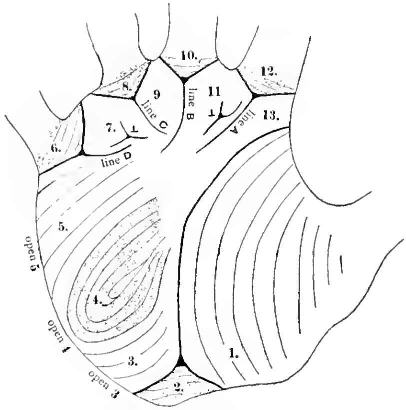

FIG. 3. DIAGRAM OF A LEFT PALM, showing the designations to be used in making the descriptive formulæ. Compare with Fig. 7.

When a pattern is not present in this region, 3 may signify approximately the lower third of the entire outer margin, and 5 the remainder.

In the majority of cases a main line will terminate in one of three ways, it will either (1) open freely along the outer margin; (2) cut through an interspace between fingers or (3) it may fuse with another main line, forming a loop. In this latter case each of the two lines involved may be considered as terminating in the triradius of origin of the other and be described by the corresponding number. Aside from these three possibilities, there is an occasional fourth one produced by the presence of what may be designated '*lower triradii.*' So far as has actually been observed (in above 600 hands) these may occur in but two places, as designated in the diagram (Fig. 3) by inverted ⊥s in the 2d and 4th of the digital interspaces (counting that between the thumb and the first finger as the 1st), but there is morphological ground for expecting one also in a corresponding position in the 3d interspace. When a main line terminates in one of these triradii it should be designated by a ⊥, with an exponent signifying the space to which the ⊥ belongs; thus $\perp^{7}$ or $\perp^{11}$ as the case may be. In addition to these, pattern triradii may occur in connection with the thenar and hypothenar patterns, and of these the second, $\perp^{H}$, comes into occasional relation with line A.

Having now a method by which the course of the four main lines may be designated by means of a sequence of four figures, let us illustrate this by a few cases taken at random, and represented by the tracings given in Fig. 4.

For these the main line formulæ will be as follows:

(*a*) 5.7.9.11.
(*b*) 5.5.9. 9.
(*c*) 2.7.8. 11.
(*d*) $\frac{4}{3}$.6.9.10.

In these the third line of (*c*) is designated by 8, the number for its point of origin, since it exhibits a course not unusual for it, but never found in the other lines, that of running down into a loop and not emerging, so that it can not be said to have a point of termination. In order to obtain formulæ enough to work with, we may add to the above that of the example (Figs. 1 and 2) 2.5.7.9; also those formulæ designating the four palms figured in Fig. 6 of the previous article, viz: (*a*) 5.5.5.7; (*b*) 3.5.6.8; (*c*) $\frac{4}{5}$.6.7.10; (*d*) 5.8.10.11.

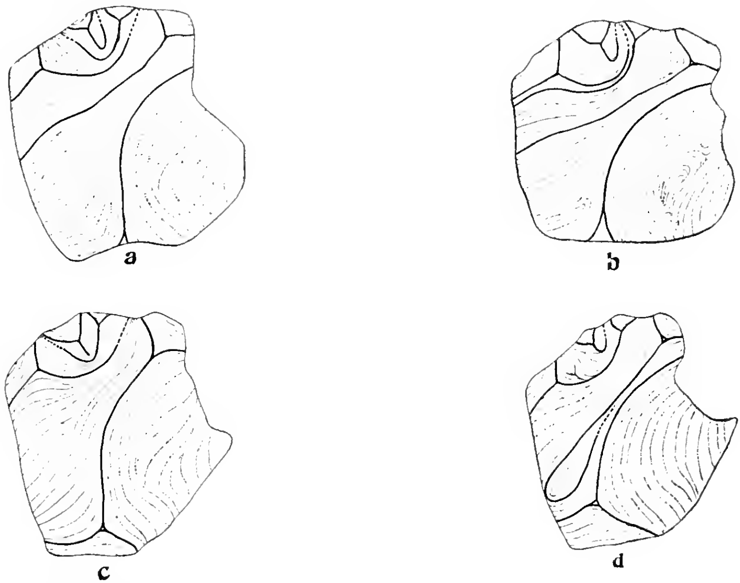

FIG. 4. TRACINGS OF FOUR LEFT PALMS, showing various line formulæ. (*a*) 11.9.7.5 [Collection No. 109]; (*b*) 9.9.5.5 [Collection No. 323]; (*c*) 11.8.7.2 [Collection No. 30]; (*d*) 10.9.6.$\frac{4}{3}$ [Collection No. 32]. In (*a*) there is a parting in place of the carpal triradius; in (*b*) there is a well-developed thenar pattern; in (*c*) line *C* is very short and runs into a loop where it ends abruptly; in (*d*) the third lower triradius is present, assisting in the formation of a pattern.

To arrange these or any number of formulæ in definite order it will be necessary only to make the first subdivision in accordance with the first designation (*i. e.*, that of line A) and so on with each designation in succession, employing the usual numerical sequence. A fraction may be marked by its numerator alone, since the denominator is nothing more than an added specification or descriptive mark, and the sign ⊥ may take precedence of all, ranking before the figure 1. By this means the nine formulæ referred to above would be arranged as follows:

2.5.7.9.	$\frac{4}{5}$.6.7.10.	5.5.99. .
2.7.8.9.	$\frac{4}{3}$.6.9.10.	5.7. 9.11.
3.5.6.8.	5.5.5.7 .	5.8.10.11.

Although, as given in all of the above illustrations, the natural order of sequence in the four designations of each formula is from the line A to line D, it happens that of the four, A is the most uncertain in its interpretation, and is the only one concerning the designation of which differences of opinion would be likely to occur. It is unfortunate to begin with this especial one and thus be liable to be put on the wrong track at the outset, and it appears to be better to *reverse each formula,* beginning with line D and ending with A. This would lead to a rearrangement, not only of each formula which would be simply reversed, but also of the order of sequence of the whole, so that the nine formulæ used above would become rearranged as follows:

7.5.5.5.	9.8.7.2.	10. 9.6.$\frac{4}{3}$.
8.6.5.3.	9.9.5.5.	11. 9.7.5.
9.7.5.2.	10.7.6.$\frac{4}{5}$.	11.10.8.5.

in which a given formula would be as easily found as in the other order, with the advantage of having the uncertain designation in the fourth place instead of in the first.

Of course it can not be known, at least as yet, what is the total number of *main line formulæ* which occur in the human hand, but in this regard the following table will be of interest, which gives in the regular order of sequence the formulæ of the hands of 100 American female college students, 100 rights and 100 lefts, and shows the number of times each formula occurs in each hand.

TABLE I.

Formulæ.	L.	R.	Formulæ.	L.	R.	Formulæ.	L.	R.	Formulæ.	L.	R.
$\perp^3$. 7.5.5	1	1	8.6.5.5	2	6	10. 7.6.5	3	4	11. 8.7.2	1	2
$\perp^3$. 8.7.5	1	0	8.7.6.5	0	1	10. 8.6.3	0	1	11. 8.7.3	1	0
$\perp^3$. 9.5.5	1	1	9.7.5.$\perp^1$	1	0	10. 8.6.5	1	2	11. 8.7.4	0	2
$\perp^3$. 9.7.5	0	1	9.7.5.1	1	0	10. 9.6.2	1	0	11. 8.7.5	4	3
$\perp^3$.10.8.11	0	1	9.7.5.2	3	1	10. 9.6.3	1	0	11. 8.9.5	0	1
7.$\perp^3$.5.4	0	1	9.7.5.3	3	2	10. 9.6.4	1	1	11. 9.7.$\perp^{\text{H}}$	1	1
7.5.3.2	1	0	9.7.5.4	0	4	10. 9.6.5	2	2	11. 9.7.$\perp^1$	1	0
7.5.5.2	2	0	9.7.5.5	5	11	10.10.6.5	0	1	11. 9.7.3	2	1
7.5.5.3	6	1	9.8.5.3	4	1	10.10.8.5	0	1	11. 9.7.4	2	0
7.5.5.4	1	1	9.8.5.4	1	0	11. 7.5.3	1	0	11. 9.7.5	4	22
7.5.5.5	2	2	9.8.5.5	2	2	11. 7.5.5	1	0	11.10.8.$\perp^1$	0	1
7.9.5.3	1	0	9.8.7.5	0	1	11. 7.7.1	1	0	11.10.8.4	1	0
7.9.5.5	0	1	9.9.5.3	1	0	11. 7.7.2	1	0	11.10.8.5	1	4
7.9.5.11	1	0	9.9.5.5	2	2	11. 7.7.3	1	1	11.11.8.5	0	1
8.6.5.2	2	0	10.7.6.2	5	0	11. 7.7.4	1	0			
8.6.5.3	9	4	10.7.6.4	1	0	11. 7.7.5	8	4			

By this it will be seen that the total number of formulæ represented in the 200 hands is 61, that there are 48 separate formulæ in the left hands and but 38 in the right. Of the 48 left hand formulæ 23 do not occur in the right, and of the 38 right hand formulæ 13 are not found in the left, 25 being common to both. The commonest formula

for the left hand is 8.6.5.3., which occurs in 9 per cent. of the cases, while for the right hands the commonest formula is 11.9.7.5., occurring in 22 per cent. of the cases. The records from so small a number of cases can not be conclusive, but it would seem both by the number of formulæ represented and by the smaller percentage of occurrence of the commonest formula that the left hand is much more variant.

From this table there may be also calculated the amount of latitude allowed in the positions assumed by each line and the percentage of occurrence of each terminus of each, the results of which are given for convenience in a separate table, as follows:

Table II.

Terminus.	Line D.			Line C.			Line B.			Line A.		
	L.	R.	Both.	L.	R.	Both.	L.	R.	Both.	L.	R.	Both.
$\perp^{H}$	—	—	—	—	—	—	—	—	—	1	1	2
$\perp^{1}$	—	—	—	—	—	—	—	—	—	2	1	3
$\perp^{2}$	—	—	—	—	—	—	—	—	—	—	—	
$\perp^{3}$	3	4	7	—	1	1	—	—	—	—	—	
1	—	—	—	—	—	—	—	—	—	2	0	2
2	—	—	—	—	—	—	—	—	—	16	3	19
3	—	—	—	—	—	—	1	0	1	30	11	41
4	—	—	—	—	—	—	—	—	—	8	9	17
5	—	—	—	12	4	16	53	41	94	40	74	114
6	—	—	—	13	10	23	15	12	27			
7	14	6	20	37	29	66	29	38	67			
8	13	11	24	15	15	30	2	8	10			
9	23	24	47	21	32	53	0	1	1			
10	15	12	27	2	8	10	—	—				
11	32	43	75	—	1	1	—	—		1	1	2

It will be seen by this that the commonest position for line D is 11 (between the index and middle fingers), a position which occurs in 75 out of 200. Similarly the commonest position for line C is 7; for line B, 5; and for line A also 5; but, curiously enough, the commonest actual formula is not 11.7.5.5., the combination of these. This table also shows that line D may oscillate in its position from the interspace between the ring and little fingers to that between the middle finger and the index; that line C swings between an open position and the same limit as that of line D, and so on.

In the employment of these line formulæ as a primary classification it seems advisable for several reasons to employ that of the left hand first, which will be seen to divide a series into between 40 and 50 compartments, and since the right hands appear to vary independently or nearly so, the addition of the line formulæ of those would subdivide each of the 40 or 50 into about the same number of lesser compartments, or in all approximately 45^2 or 2,025.

That is, if the hand-prints of a city of 100,000 inhabitants were arranged in accordance with the line classification alone, there would be needed over two thousand compartments, with, theoretically, about

50 in a compartment. As practically worked out, the distribution of these prints in compartments would be an unequal one, and while certain of the compartments would have but a single representative, or be even empty, some of the others would have a much larger number than fifty, possibly even several hundred.

But the line formulæ are but a primary classification and do not by any means exhaust the resources of these very varying parts. As a *secondary classification*, for the farther subdivision of the palms, to be appended to the first and employed whenever expedient, the use of a *pattern formula* may be suggested. This is based upon the irregular occurrence of patterns such as occur normally in the simian hand and appear sporadically upon various localities of the human palm.

If we count as a pattern each place where there is a definite loop, whorl or noticeable disturbance of the usual even course of the ridges, although by doing so we violate certain of the underlying morphological principles as shown by the comparison with other mammals, we may expect to find any or all of five patterns, located as described in the previous article and corresponding roughly to the divisions into which the palm is divided by the lines of interpretation, viz., one *thenar*, one *hypothenar* and three *interdigitals* (*palmar* of the previous paper). Of these the thenar, of rare occurrence among people of the white race, is morphologically composed of the vestiges of two, a genuine thenar and the interdigital which corresponds to the interval between the thumb and index; the three interdigitals lie below the three intervals between the fingers from the index to the minimus; and the hypothenar appears upon the large eminence of the same name which forms the outer boundary of the palm.

A pattern formula will thus need five places, one for each of the five patterns in a prearranged order, and, again adopting the principle of placing in the first position a very obvious one, about which there is no doubt, the order suggested may be, *hypothenar, thenar, first, second* and *third interdigital*. When any one of these is present, it may be designated by an abbreviation, such as a capital H for hypothenar, Th (or better, the Greek θ) for the thenar, and 1, 2 and 3 respectively for the others. When absent, 0 may fill the position, and when there is merely a rudiment, a small r may be added to the 0 as an exponent. Thus a few representative pattern formulæ would be the following, taken from actual cases:

H.0^r.1.2.3	0 0 0.0.3
H. 0.0.2 3.	0.0 .1.2.3.
H. 0.0.0.3.	0. 0.0.2.3.
H. 0 0.0.0	0. 0.0.2.0.
0. 0.0.2.0.	0. 0.0.0.3.
0. 0 0 2.0.	

The order of arrangement for each position would be naturally to consider the signs of the patterns as precedent to zero, an arrangement which it will be noticed, has been followed in the above list. A rudiment, like Galton's descriptive suffixes, is disregarded in the arrangement, and counts like other zeroes.

FIG. 5. PRINT OF A RIGHT SOLE [COLLECTION NO. 112] SHOWING A HIGH DEGREE OF COMPLEXITY, and presenting difficulties in formulation. There are two lower triradii, probably the first and second, in which D and B [IV and II] terminate respectively; the triradius of line C [=III] is beyond the limit of the print and its location is in part conjectural; the second and fourth digital lines curve downward across the palm.

Morphologically the same pattern, *i. e.*, one in a given position, may differ considerably in regard to its mode of formation, the presence or absence of 'pattern triradii' or those concerned in its structure, the shape of the pattern itself, its degree of completeness and so on, and all these attributes may be easily added by means of a series of easily devised descriptive signs, like the 'descriptive suffixes' of Galton, and used as exponents, having, like the exponent r, no influence upon

the arrangement of the formulæ, but simply completing the description.

Should a third classification be necessary, the presence, position or absence of the carpal triradius would furnish one, and for a fourth subdivision a counting of certain of the ridges, like those between the digital triradii as Galton does in his finger-tip system, might be suggested. In the last instance, where the decision of a definite case rests upon the identity of a certain individual, actual prints taken from his palms should be compared with the set in the collection which most closely corresponds in the formulæ to them, and the decision should be reached by the study of the minutiæ, *although there could hardly be a mathematical chance of a comparison going as far as that unless it was a case of actual identity.**

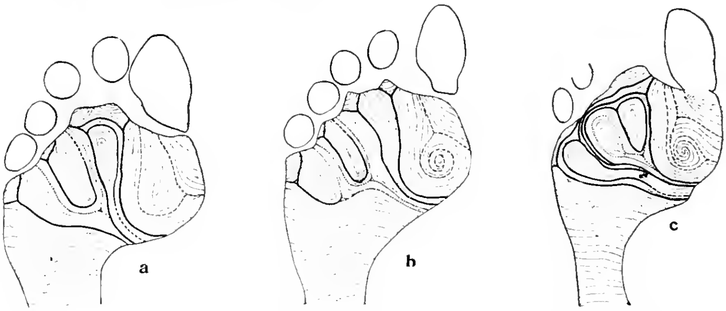

FIG. 6. TRACINGS OF THREE LEFT SOLES, showing various relations of digital and main lines. (*a*) Lines *A*, *B* and *D* are open; line *C* is recurved and opens at 9; the third digital line is recurved around a pattern: the first and second digital areas are confluent; there is a single lower triradius [Collection No. 156]. (*b*) Lines *A* and *B* are open: line *C* is recurved; line *D* terminates in a lower triradius (the third ?); the digital lines are all normal and the digital triradii are distinct; there are two lower triradii [Collection No. 86]. (*c*) Lines *A*, *C* and *D* are open; line *B* is recurved around a pattern and fuses with one of its own digital lines; the digital lines are in general much modified and the digital areas are all confluent; there is but one lower triradius, the first [Collection No. 59].

The previous pages have treated of the hands alone as though they were the only possibility of the system, but the soles of the feet exhibit fully as great a diversity in the course of their ridges, and their use in addition to that of the hands would furnish so complete a means of subdividing a collection of prints that the secondary classification, *i. e.*, that which concerns the patterns and the carpal area, would hardly be necessary except to complete a description. The feet as well as the hands possess four main lines originating from the digital triradii, and as their formulæ are nearly as variant as are the others, the subdivisions rendered possible by the use of all four members are well-nigh infinite in number (see Figs. 5 and 6).

* Consult in this connection my comparison of identical twins, which are in all probability nearer alike in the palm and sole markings than are any other two human beings, and which nevertheless differ to a noticeable degree in the minutiæ. *Amer. Jour. of Anat.*, Vol. I., No. 4. 1902.

Thus if, as shown above, a set of formulæ would be divided into upwards of 50 divisions by using the left hand alone, and if each of these would be farther subdivided by adding the formulæ of the right hand, producing 2,500 divisions in all, the addition of the left foot to these might increase the number to 2,500 × 50, or 125,000, and these would become 7,250,000 by the use of the right foot, or enough to characterize every citizen in a large state or small country, employing merely the *primary* classification. It must be remembered, however, that these are theoretical figures and that the actual combinations of lines may not be as great, nor would the various kinds be as regularly distributed; yet enough has been shown to prove that the number of separate actual combinations of the line formulæ alone, if both the hands and feet are employed, would be very great.

In a sole print the characteristic features are mainly distributed along the ball of the foot, anterior to the hollow of the arch, and while in a general way they are similar to those of the hand, there are also numerous important differences, some of which will be seen in Fig. 5, a print which represents a more complex condition than is usually seen, and in the tracings given in Fig. 6. The four main lines of the sole, although arising from digital triradii, usually curve towards the inner instead of the outer side, and when open, are apt to converge at the inner margin almost or quite to the point of fusion. There is also almost always upon the thenar region or ball of the great toe a conspicuous pattern, which may be termed the *hallucal* pattern. This possesses one or two, and possibly three triradii, of which the upper one is the proper digital triradius of the great toe, usually unrepresented in the hand; while there is often a second one upon the extreme inner margin, sometimes shown only by rolling the foot a little during printing. The hallucal pattern shows much variation and is easily divisible into a series of types, which well serve the purpose of a secondary classification. Lower triradii are of far more frequent occurrence than in the hand, and are often located so near one another through the convergence of the interdigital areas that it is difficult or impossible to attribute them to any one of them.

Probably the greatest barrier to the formulation of sole conditions in the same way as in the case of the palms lies in the position of the digital triradii, which are apt to be situated in the hollow beneath the toes and thus beyond the margin of a print—a condition especially apt to occur in the case of the third one, *i. e.*, that at the base of the fourth toe; again, the relationships of the triradii are often complicated by the fusion of two or more digital areas with one another and the consequent displacement of the digital lines, which may simply pass one another upon the digital areas or curve downwards over the ball of the foot as

is the case with the second and fourth digital lines in the print given here (Fig. 5).

These difficulties, especially that of the extra-limital position of the digital triradii, certainly prove a barrier towards the application of the same system as in the palm; yet, with some adjustment to conditions, this would still seem to be feasible. A diagram assigning numerical designations to the different terminal regions is given here (Fig. 7) which may be compared with the similar one referring to the palm (Fig. 3).

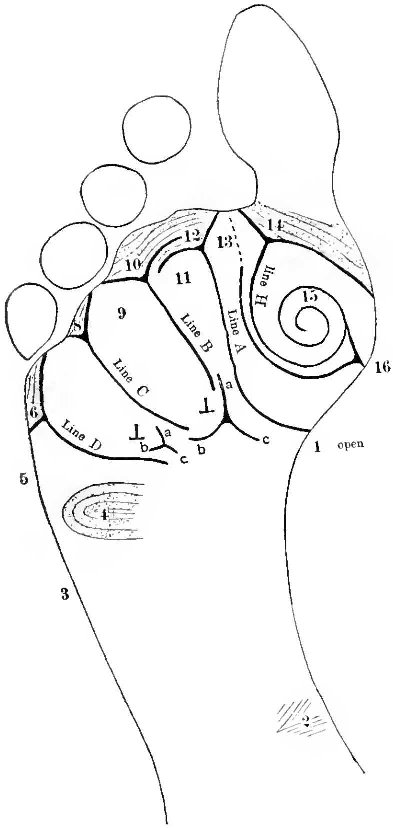

FIG. 7. DIAGRAM OF A LEFT SOLE, showing the designations to be used in making the descriptive formulæ. Compare with Fig. 3.

A more detailed account of the sole formulation is not within the space limit of the present article, but enough has been given to suggest how this may be accomplished. I would especially emphasize the practicability of the use of the hallucal pattern, perhaps even in a primary classification, which recommends itself by its large size, its conspicuous character, and its ready divisibility into definite types.

Lastly, there remains only a short discussion of the means of recording and filing away prints, the amount of space they would occupy and their consequent feasibility as a means of recording all citizens, as advocated in the previous article. The prints themselves should be taken upon smooth but not glazed unruled paper of a suitable size, one of about 35 x 21.5 cm. (14 x 8½ inches) for the hands, and one of 35 x 28 cm. (14 x 11 inches) for the feet. Upon each of these the respective prints should be arranged in the natural order, that is, the left upon the left side, etc. There is enough blank paper left in such a piece to record any details necessary about the person; the name, date of birth, nationality, and even the Bertillon measurements.

As in the Galton system the formulæ may be written at one end, most conveniently the left, so that an especial case could be found by turning over a pile of papers as in selecting a page in a book; or else

each set of prints may be simply numbered, and placed consecutively in shallow drawers, with 50–100 in a drawer, while the classification may be made by means of a card catalogue, which would contain a numbered card for every individual, arranged in accordance with the system just described. I have arranged my own print collection upon this latter system, the prints being numbered and arranged consecutively in the order taken, while the corresponding cards are classified in accordance with the formulæ, those of the left hands taken first, and subdivided by those of the right.

As for the space required for a collection. If the prints are filed in shallow drawers or slides holding 50 sets each, a collection of 100,000 sets could be accommodated in 2,000 drawers; and allowing a frontage of 16 x 2 inches for each drawer with its surroundings, these would make a cabinet 6 feet high and composed of 56 perpendicular stacks which together would occupy a wall length of 75 feet. An 18-drawer card index with a capacity of more than 20,000 3 x 5-inch cards, as taken from a recent catalogue of office furniture, is 44 inches wide and 14 in height, and the five necessary to accompany the collection in question would form a single stack 6 feet high and 44 inches wide, which will add approximately four feet to the seventy-five given above. Thus a room having 80 feet of wall, linear measure, or a smaller one with a double stack running through the center, would be amply sufficient for the entire collection, properly arranged.

This calculation appears to answer in the affirmative the question of the practicality of keeping palm and sole records of all citizens as advocated in my previous article. M. Bertillon has pointed out the numerous cases in civil life in which one's identity is in peril, and looks forward to a future in which some record, based upon physical characters, will be made of every citizen, but the trouble and inconvenience attending his own system of measurements and the fact that they are applicable during adult life alone, would leave them hardly to be considered for such a purpose.

The palm and sole system, which I originally presented as an extension of the system of Mr. Galton, appears to supply the need in this respect, as the records are easily taken, unchanged from birth to death, quickly compared, either with the hands and feet themselves or with other prints, and capable of brief characterization and of accurate classification by means of simple formulæ, to all of which may be added, as their most important advantage, that of absolute certainty, while the Bertillon measurements afford no more than a strong probability.

Prints could be taken in each township or municipality, and filed away in any convenient spot, perhaps the court house of each county

seat. They could be taken in connection with the school registration, either when first entering, or better yet at the age of twelve to fifteen. There can be no question as to legal right in compelling such records, since there is no serious objection to compulsory vaccination, a far more serious operation, and one incurring a slight indisposition and a permanent change in the system, the nature of which is as yet unknown.

Similar records could be taken by the various civil and religious institutions in which the identity of an individual is apt to be called in question. Banks could require an imprint of the left palm upon the inside cover of bank-books; business men could issue checks with a fac-simile engraving of the palm of their own left hand covering the face; insurance companies could keep a palm and sole list of their clients; the Geary law would be rendered a certainty if the certificate issued to each Chinaman bore, besides the photograph, a single palm print, and churches could file away palm and sole prints with their baptismal records.

In the words of Bertillon, the founder of anthropometric identification: "La constitution de la personnalité physique et de l'indéniable identité des individus arrivés à l'âge adulte répond, dans la société moderne, aux besoins les plus réels, aux services les plus variés. . . . En un mot, fixer la personnalité humaine, donner à chaque être humain une identité, une individualité certaine, durable, invariable, toujours reconnaissable et facilement démontrable, tel semble l'objet le plus large de la méthode nouvelle."*

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* 'Instructions signalétiques,' 1893, Introd., p. lxxxiii.

SOME OF THE EXTRA-ARTISTIC ELEMENTS OF ESTHETIC EMOTION.

By JOHN COTTON DANA,
FREE PUBLIC LIBRARY,
NEWARK, N. J.

MY work in a library has brought me in contact with the art interests of a great many people. Most of these people have been of the average, well-to-do, clerical, commercial and professional classes in this country. Representatives of women's clubs and of art classes of all kinds have been common among them. Many had traveled or were making studies preparatory to visits to art centers abroad. The modern public library thinks the promotion of interest in art in its community is a proper part of its work. With this in view it buys expensive books on art and photographs of paintings, sculpture, architecture and other things in the field of art. The library's close connection with the schools also makes it easy for the librarian to keep in touch with their work in drawing, design and general art instruction. I have had unusually favorable opportunities to learn about the art interests and the esthetic perceptions of that very interesting class of American women, the public school teachers. From them and from supervisors of drawing in the schools I have learned something of the interests of children in pictures and of their capacity for esthetic cultivation. The libraries I have been connected with have made great use in the schools of illustrations and decorations found in certain periodicals; not only of pictures from art journals, but also of material published, not for its art interest, but for its illustrative interest. For students of design, collections have been made of head- and tail-pieces and initials, from many sources. Designs for wood carving, embroidery, iron work and the like have been gathered and arranged. Illustrations have been collected—sometimes by the children themselves—and arranged by artists, by subjects, by methods of reproduction and by media used in the original. Collections have been made for story-telling purposes, and to illustrate history, geography and nature-study. Reproductions of famous paintings, sculptures and buildings have been gathered and classified. I speak of this by way of introduction: to explain my interest in the subject of art: and to give grounds for presuming to speak upon it. The collecting of these pictures, the purchase of art books and the encouraging their use have naturally brought me into close touch with the very representative

group of Americans who patronize the free public library. I believe I know something about their way of looking at the subject of art; and that I know, consequently, how art is regarded by about 99 per cent. of the fairly well-to-do and moderately rich in this country. My interest in the subject, enhanced by the opportunities I have mentioned, has naturally led me to take note of art in the American home, and of the light it throws on the art knowledge and esthetic sensitiveness of the American people. My observations in this direction have confirmed me in the conclusions, herein noted, to which my work in the library had led me.

Most discussions of esthetics ignore certain common, every-day feelings which seem to be important factors in the appeal which works of art make on our attention. I have here tried to describe the nature and origin of some of these feelings, and to show that they are among the most universal and the simplest elements of esthetic emotion. I call them extra-artistic elements, because by the professional artist they are not considered to lie within the artistic field.

The physiological factors in esthetics are, in a certain sense, more fundamental than the familiar feelings I discuss in this essay. They go to the very bottom of the pleasurable sensations which the sight of certain objects gives us. But we do not yet understand them. A spot of color probably gives pleasure—under proper conditions—even to the most uncultivated observer. Savages and even some of the lower animals have this much of esthetic feeling. Meaningless arrangements of several colors probably give greater pleasure to some, even of the entirely untrained, than does the single spot of one color. Flat design in black and white, quite without suggestion of any kind, arouses agreeable sensations in some, but probably only in a few of those who have never given thought to the subject. That is, pictures, considered simply as flat, colored designs with no regard whatever to what they portray, may produce an agreeable physiological effect on some of those who see them. This direct physiological effect is, as I have said, little understood. It sometimes, perhaps commonly, forms a part of the group of pleasurable feelings which picture-gazing evokes. It is fundamental to be sure; but with nearly all observers it is of slight importance in comparison with the mass of agreeable sensations whose nature and genesis I have outlined below.

Most of us first note a picture which we know is popularly admitted to be a work of art with a pleasure which comes of being in the fashion. It is the custom to enjoy it. We like to know and feel that we are following the custom. We find it easy to say, as all others do, that it is pretty and attractive; and so saying we get the pleasure of conformity; of being in the mode. This kind of picture-enjoyment lies upon the surface, is easy to acquire and comes naturally to all of

us; and any picture which has once gained wide repute, thereby gains popular esteem, gives much pleasure, and seems to serve a proper purpose by virtue simply of being in the fashion, even though it have little to commend it to the wise critic. The word fashion carries often an implication of censure. Such censure is not intended in this case. To wish to see what others have seen is natural and proper. The mistake would lie in assuming that this kind of pleasure from picture-gazing is not present with all of us, and is not a proper element in esthetic emotion.

To see old friends again after a time of separation always gives us pleasure. The emotions which go with the act of recognition are so generally agreeable that we greet with considerable warmth of feeling even those old acquaintances we have never much cared for if we meet them after long separation or at a distance from the scenes where we once knew them. This recognition-element among the factors of pleasurable emotion lies at the bottom of much of our joy in the familiar quotation, of our admiration for the classic in literature and the familiar in art. A picture often spoken of, often alluded to in print, seen occasionally, even in the simplest or crudest reproduction, is at once recognized, and at once gives us the pleasure of recognition, when seen again. This manner of picture-appreciation lies, of course, close to the pleasures of memory, to the indulgence of habit, and to the complacence of conservatism; just as the pleasures aroused by the picture which it is the fashion to admire lie close to the self-satisfaction born of conformity to the prevailing moral code. These fashionably-born and habit-bred emotions form a large part, a very large part, of the delight we find in picture-gazing. Art galleries are full of people who gain little from their visits there beyond these simple and familiar emotions. Yet in the discussion of esthetics they are commonly almost ignored. The origins of the feelings which are aroused by works of art are assumed to be complex, peculiar and quite remote from every-day life; whereas the most dominant of them lie close at hand, in conformity and habit. In the field of literature we see this truth very clearly illustrated. The classics of one's native tongue are chiefly enjoyed because they are familiar. Often, probably commonly, they have a power to move us which is due to their content, or to our knowledge of the peculiar circumstances under which they were produced, or to their relation to a widespread creed, or to the personality of their writers, or to the influence of their promoters or expositors, or to their particular aptness of phrase, or to the peculiar sensitiveness of a few of their many readers to the spell wrought by special arrangements of words. But, once having become imbedded in the popular mind, once having become the accustomed reading of a generation or two, they hold their power very largely through the fact that they are easily

recognized, are habitual visitors, and arouse often the joy of recognition. The St. James version of the Bible is perhaps an example of the best possible use of the English of its time. But of this we cannot be sure. As a book it has long been popular—on other grounds than those of style. Being popular it molded our forms of expression for generations. All our speech harks back to it. To read it is to catch in every phrase a pleasing echo of the language of our own time, and this regardless of the agreeable familiarity of thought and incident. We recognize it, and delight in it. If circumstance had cast that version into a different form we should, no doubt, admire it none the less; and our language would be different from what it now is, perhaps better.

Allied to both fashion and recognition as an element in esthetics is curiosity; not the inquiring curiosity of the seeker, but the passing curiosity which we take in uncommon things. The picture much talked about—this is the one we wish to see. Having seen it the emotional tension is relaxed, and we have an agreeable sense of satisfaction. Near to this and perhaps part of it is the pleasure given by the sight of a picture which is rare or ancient or high in price, or one which was made with much labor or with unusual technical skill. The patch-work quilt of a thousand pieces made by a woman of seventy-five without the use of glasses, this gives great pleasure to its observers. It is a curio. To most observers it is looked at with a pleasure of like origin to that with which they gaze upon a painting by an old master. I am not condemning this form of emotion. I am simply setting it down where it belongs as forming a part in many cases of the pleasure of picture-gazing, as a part of esthetic emotion. Much of the furnishing of the homes of people of wealth and cultivation—being rare, costly and representative of great labor and much technical skill—gives to its owners a pleasure of like origin with that imparted by the crazy quilt.

Kinship in knowledge is a bond of friendship. The beginning of sympathy is like-mindedness. We cannot care much for those we do not know; we know those who know the things that are known by us. Meeting in a distant land one alien to us in every way, but familiar with the same home scenes, a friend of friends of ours, we have for him at once a touch of sympathy, and find pleasure in our meeting. So, if we look upon a picture in company with others who are with us in our enjoyment—even when, as is most often the case, the enjoyment is born of fashion, habit and curiosity—we have a sense of companionship with them, a pleasurable feeling born of a common interest, which we ascribe as to its origin to the picture itself. In fact, the picture, as a work of art, is not the cause of our enjoyment at all. A tight-rope walker or a sacred relic would serve as well; perhaps better in many cases. We simply have widened and increased our

sympathies through the acquisition of a new point of contact with our fellows.

Almost all pictures tell a story. Those which seem not to do so at first sight are usually found to be full of meaning on second look; and a very large proportion of all the pictures most commonly seen, those in the illustrated journals, are intended almost solely as aids to narration. Stories are dear to us all. We are eager to hear them, to read them, and especially to see them. One that is told by a picture, and so is flashed upon the mind in a glance of the eye, adds to other possible excellencies those of brevity and surprise. In a picture we look usually first for what it tells—that it gives us, in a flash, a bit of life from a new point of view, seen in a different light, touched with humor, pathos or other sentiment—this is commendation enough. A portrait is to most a story picture. It tells more about the person portrayed than many pages of biography, and interests chiefly by what it tells.

It is usual to decry this story-telling element in pictures. Mr. John C. Van Dyke, for example, in his book on 'Art for Art's sake' speaks of 'The Angelus' as having a 'literary interest crowded into it to the detriment of pictorial effect.' We can not see in the picture, he says, 'the sound of the bells of the Angelus coming on the evening air, from the distant church-spire.' 'We must go to the catalogue to find the meaning of those two peasants standing with bowed heads in a potato field.' And he says, that, 'two thousand years hence, with the ringing of church-bells abandoned and forgotten fifteen hundred years before, we would not comprehend and appreciate the picture as we now do a Parthenon marble.' Mr. Van Dyke forgets that the Parthenon marble itself also tells a story; and that it is because we know the story well, because Greece and its religion, its social life and its art are familiar that we comprehend and appreciate at once even a fragment of that country's creations. The fragment arouses our recognition-pleasure, and most strongly. It appeals to us also by what it tells of the past; it tells it easily because we are full of a knowledge which makes us fit to receive it. Suppose Greece and her temples forgotten, a Parthenon marble would be beautiful still, probably, but it would be no more easily comprehended and appreciated than would 'the Angelus' if church-bells had passed out of human memory. All pictures are illustrative; all are story-telling in a measure. It is inevitable that they should be so. They can not, as Mr. Van Dyke seems to wish to have them do, 'show deep love of nature per se, independent of human association.' The question of illustrative intent is entirely one of degree. Nor is there any rule whereby one can say how much of this element a picture should contain. There it is; there it must be. It is good, and we may rejoice that it adds its force to that of the other factors in the delights of picture-gazing.

To the story element in pictures as a cause of our enjoyment of them we must add another element closely allied to it, that of history. The historical picture is always a story picture; but it usually tells to an observer more than a mere story. If we are ourselves already familiar with the incident depicted, we gain from looking at the picture the recognition-pleasure already noted. If we are not familiar with it we take pleasure in adding to our historical knowledge the particular incident set forth in the picture. That is, in looking at historical pictures we either pride ourselves on a recognition which assures us that we are so far well-informed, or we please ourselves by adding to the sum of our knowledge.

Knowledge of the life of an artist, of his peculiarities, of striking incidents in his career, of the country and the time in which he lived —this knowledge adds much to the pleasure gained from pictures. A glance at one, if it is recognized as by an artist of whom the observer already has some knowledge, gives first the pleasure of identification cr naming—not different from that which one has who can name on sight a distant mountain peak—and next, through association the pleasure of recalling, even though vaguely, facts in the artist's life. Much of the pleasure won from pictures lies in this identification-emotion.

The pleasures thus far noted as derived from pictures are not derived from pictures only. We get the same enjoyment from looking at scenes upon the stage, at photographs of nature, at nature herself, at incidents in real life about us and from poetry, story and literature in general. This is equivalent to saying, and the saying is a true one, that most of the enjoyment of pictures is due to effects not at all associated with or flowing from 'art' as that word is generally used by artists. The artist himself, however, is by no means free from the influence of the factors already enumerated. From time to time, in his development as an artist, he has undoubtedly tried to free himself from what seemed to him the embarrassing limitations of the habit, formed in youth, of getting from pictures pleasures born of fashion, curiosity, sympathy and story. He never succeeds in doing this. He sees all pictures as he does all art—as I have said in discussing the presence of the story element in all art—through the medium of his own past experiences and of his own character. He sees them first as an animal, as a social being, as a person fashioned by the age and country in which he lives. As an artist, however, as a person skilled in his calling, the things that usually most interest him are technique, design, color, light and shade, line, and manner of laying the paint on the canvas. It has probably always been the fashion for artists themselves to speak rather scornfully of the interests aroused by and the pleasure taken in pictures from the point of view of the story or of

the other elements already mentioned, and to think of them as lying outside the field of art proper. But the artists who are of the broader view readily admit the importance in painting of these extra-artistic features. From the point of view of craft, of technical skill in painting, these matters of line, and color, and light and shade, and arrangement, and method of applying paint, all are of great importance. But only with the craftsman who is unduly interested in the question of skill do these purely artistic matters seem of greater importance than the factors of enjoyment already mentioned.

If I have been right in this analysis of the pleasures gained from pictures, we may describe the picture-gazing of the average person somewhat as follows: He likes the color; he likes to look because others look; he likes to look because he enjoys seeing an old friend; because he has the habit of looking; because he enjoys seeing the curious; because he enjoys the sympathy with his fellows which comes from enjoying the same objects with them; because he enjoys the story of the picture; because the picture renews for him an incident in history; because considered simply as a design the picture is to his thinking well made and he finds agreeable the relation of its lines and its colors and their arrangement, their harmonies and their contrasts; and because, having skill as a painter, or knowing of that skill, he is interested in the manner in which the artist in question laid on his paint.

These remarks on some of the simpler elements of esthetic emotion as shown in picture-gazing may seem commonplace, may seem too obvious to be worth the saying. But the obvious and the commonplace —these very often escape us. They are particularly ready to do so when we speak of beauty, art and esthetics. In this field words are very often merely counters, not real coin. All of us have our pleasurable emotions when we look upon beautiful things, else why do we call them beautiful? And the very words in which we speak of things of beauty seem themselves to have a power to move us; and we ascribe to them meanings when in fact they are often only meaningless echoes, faint, but still able to stir our emotions.

Beauty as a factor in the pleasures of picture-gazing, this I have not named. Yet the whole discussion is concerning it. For, if a picture, or any other object gives us the pleasure described it must possess the subtle quality of beauty. That quality itself cannot be described. When we see a beautiful thing we know it. What more can be said? If experts, who are careful observers of the things which people say they find beautiful, if experts in esthetics say the beauty of a certain object is of the better kind, their statement is worthy of attention. It is difficult to say of beauty and the critics more than this.

KARL LAMPRECHT AND KULTURGESCHICHTE.

By Professor WM. E. DODD,

RANDOLPH-MACON COLLEGE.

DURING the last ten years a fierce war of words has been waged in Germany concerning the nature and scope of history. It is known as the 'Kampf um die Kulturgeschichte' and almost every historical scholar in the Empire has been forced to take either the one side or the other. This 'Kampf' which seems to mean so much for history and its writing began in 1893 with the appearance of the first volume of 'Deutsche Geschichte' by Karl Lamprecht, professor of history in the University of Leipzig. Leipzig and Berlin have been the centers of the opposing forces, and seldom has a learned controversy been conducted with so much animus. The question at issue is: Is history a science or an art? Lamprecht boldly asserts that it is a science, while his opponents maintain that it is and must always remain an art. The adherents of Lamprecht have been dubbed 'Lamprechtianer,' while the enemies of the new movement call themselves 'Jungrankianer.' It will thus be seen that the name and fame of the great Ranke have been enlisted on the conservative side of the dispute.

American scholars have troubled themselves but little about a contest both sides of which are supported by so much of truth. In fact little has been said or written in this country about Lamprecht or Delbrück, the leading champion of the Ranke school. Only one article and one review have come to the attention of the writer; the article appeared in the *American Historical Review,* of April, 1898, the review in the same publication of July, 1902. Yet the word 'Kulturgeschichte'—Lamprecht's slogan—is not unfamiliar to most of us, and quite often in addresses and papers on history and its teaching the principles laid down in the works of the Leipzig professor are given no little prominence. In some quarters, however, the unconscious Ranke influence has found expression in slurs on the claims of 'Kulturgeschichte'—history as a science, as Lamprecht insists. Still it is safe to say that the ideas advanced by the new school of German historians find a more general acceptance in our country than in any other, and this without our knowing just how it comes about. The cause of it is, perhaps, the reasonableness of the tenets of the Lamprecht school, the practical cast of mind of American scholars and our comparative freedom from the trammels of tradition and class prejudice.

Karl Lamprecht was born near Wittenberg in 1856; received his earlier training at Pforta, the celebrated Prinzenschule, and won his Doctor's degree from the University of Leipzig in 1879. The student was father of the scholar; his thesis was of such extraordinary character that the department of history to whose head it was offered refused to accept it. So the present head of the same department was compelled to take his degree as a political economist. Young Lamprecht was scarce hopeful of entering upon the professorial career, so scant were his means and so expensive it was and now is in Germany to become an instructor in a university. He engaged himself to teach in a private family in Köln, but while employed in this capacity he unexpectedly attracted the attention of a wealthy burgher of that city named Mevissen, who supplied him with the means of entering the University of Bonn as a docent—usually the first step to a professorship. Lamprecht's initial work, the investigation of the condition of the peasantry of the Rhineland at all stages of German history, brought him into disagreement with most of his seniors in the university faculty. He continued his studies in this direction, however, without interruption until he had founded *The West German Magazine of History and Art,* the 'Society for the Advancement of Rhenish History' and had laid the foundations for his famous 'Deutsche Geschichte' in his first important work, 'Economic and Social Conditions in Germany during the Middle Ages,' in four volumes. All this was done during the years of 1880 to 1886 and while he was only a docent—an activity which bespoke the astonishing energy of the present professor. A year or two after the appearance of 'Social and Economic Conditions in the Middle Ages' Lamprecht was called to Marburg as ordentlicher professor, very much to the surprise of the wiseacres, who had opposed him at every turn at Bonn. In 1890, when only thirty-six years of age, he was made full professor of history at Leipzig, where he has been the directing spirit in the faculty of modern history ever since; his co-workers and assistants in this department number about a dozen and his students each semester average 350 to 400; in the historical seminars there are from ninety to one hundred men taking special training in *Kulturgeschichte.* These students come from all parts of the civilized world. It is not difficult then to understand what an immense influence Lamprecht is exercising on the present generation of historical students. Such is, briefly, the lifework of the man who has excited so much opposition in Germany. Let us examine more closely the main features of the new history and its methods.

Lamprecht divides all knowledge into two classes: the one dependent on mechanics, the other on psychology, *Naturwissenschaften* and *Geisteswissenschaften.* History is a science—a Geisteswissenschaft—dependent on psychology. It deals with the acts of men just as bot-

any, for example, deals with the manifestations of plant life. In neither case can we determine the nature of the inner, the motive-essence. The difference in the two sciences, however, consists in the fact that the historian deals with the activities of men and peoples long since passed beyond the reach of his personal knowledge. He relies upon more or less accurately attested depositions given by contemporaries or by the persons themselves, while the botanist, having the object of his investigations before him in most instances, is relieved of the task of rehabilitating extinct existences or species. The historian reconstructs the social and political characters of the past, masters the different intellectual movements, and then places each in its proper relative position, according to the most exacting methods of judgments and interpretations. The rules of accepting and rejecting evidence, of interpreting and classifying great historic events and tendencies which guide the historian in his reconstruction of the past entitle him to the rank of a scientist. The naturalist places a given animal in a certain class because of certain outward manifestations—the expression of the inner unknown forces; the historian places the historic character, whether statesman or peasant, in a certain class, by reason of the same kind of manifestations. In both instances the scientist is dealing with unknown quantities; but in both the outward activities are observed, interpreted, classified and made the basis of future judgments.

Following such a method of investigation one is prepared to appreciate, if not to accept, the second claim Lamprecht has put forward, viz., that history has not so much to do with great personages of the past as with the currents of thought, feeling or passion which produced those personages. He looks upon social, political and industrial leaders as exponents of popular or economic movements and deals with them as such in his writing. This relegates the kings and ministers of the present and past to quite insignificant positions and places the masses of the people in the forefront—a method not a little distasteful to the crowned heads of Europe.

Our new historian goes still further in his readjustment of historical method. Every people has gone through a certain more or less well-defined series of stages of evolution, *e. g.*, the Germans have passed through the following: symbolism, or the earlier and medieval history of the race; individualism, modern times to the French revolution; the age of the subjective soul-activity, or the nineteenth century to Wagner and Darwin, who introduce the present age of excitement and nervosity, if such a word may be used. It is the soul-life, *das Seelenleben*, of the people which determines the direction of national life, and this soul-activity is to be *understood* only as one fully comprehends the every-day life of the peasant, the artisan and the trader. This neces-

sitates a minute study of the hitherto neglected records of town and country life, the contracts, deeds, marriage bonds, parish lists, folklore and song, in fact everything down to the names of villages and the houses of the *Bauern*. Nothing has escaped Lamprecht's attention; and the results of twenty years of such investigation are recorded in his 'Deutsche Geschichte' (in six volumes) already mentioned. The 'common man,' who Alexander v. Humboldt had declared in 1809 could never be anything but a minute particle of the material of history, becomes with the Leipzig historian a guiding force in society, the very corner-stone of the building.

According to this method 'the making of history' which the politicians so often conceive to be their rôle in life is a very misleading term. History is not made, but it unfolds itself as a resultant of the thousand and one forces of which our leaders are but the humble exponents. The great influences which give a people their character and determine the direction of their development arise from climatic and geographical conditions, race antecedents and the reaction on these of economic forces, which forces are themselves in large measure the resultants of the above-mentioned conditions. Economic advantage and industrial aptitude determine the character of a people, not the will of leaders or leading classes.

To be sure this is not altogether a new view of history. Voltaire, suggestive in so many lines of thought, boldly proclaimed such to be the true historical method. Buckle spent twenty years in the attempt to elevate history to the rank of a science, and certainly succeeded in calling attention to the neglected influences in 'history-making'; but not in relegating governments to the positions of social machines, not in dethroning the long-worshipped heroes and martyrs of the past. Moreover, Buckle's work was in no way so intensive as that of the German *Kulturhistoriker,* and what Buckle attempted for English history, Karl Biedermann accomplished for Germany in his monumental 'History of German Civilization in the Eighteenth Century.' Biedermann was one of those liberal thinkers whose dream for the Vaterland was so rudely disturbed by the all-conquering Bismarck spirit in the early seventies. The influence of both Buckle and Biedermann was swallowed up by the idea- and hero-worship of Ranke and his followers. And this tendency was in full harmony with the prevailing political opinions. The same influence is found in England in the works of Freeman and Gardiner and Stubbs.

The appearance of the 'Deutsche Geschichte' was a challenge for opposition of which its author must have been conscious. German history writing, since 1860, as has been suggested, has been a constant imitation of the great Berlin professor, Ranke. And to understand

the *Kampf um die Kulturgeschichte* it is necessary first to review briefly the Ranke method.

Leopold von Ranke's first great service to accurate scholarship was his practical discovery of the Venetian relation. From this time on he was a most tireless student of European archives; his books are all most faithful interpretations of the contents of these store houses of history. From the time of the appearance of his 'Roman Popes' and the 'German History in the Time of the Reformation,' 1834 to 1847, a sort of ideology has prevailed in almost all historical writing not only in Europe, but in our own country. With Ranke great ideas not dissimilar to those of Plato's philosophical system furnished the *motif* according to which all his work was done. These ideas were the state, the church, the reformation, the counter reformation, etc. The individual had but to adjust himself to the greater almost God-given idea of the time; he was not the author of the idea or one of the makers of movements, as Lamprecht would have him. In truth Ranke's history deals almost exclusively with politics and political heroes, representatives of certain ideas. This idealism was a part of the prevailing philosophy, an application in history of Fichte and Hegel and Schelling in philosophy. Now the followers of Ranke, instead of adding to and broadening the Ranke method as times changed and new *Weltanschauungen* took the place of the older idealism, considered themselves fortunate if the world called them successful imitators and pupils. Great works they produced, indeed, such, for example, as Curtius' 'Greece,' Trietschke's 'Germany in the Nineteenth Century' and Mommsen's 'Roman History'; but they were all of essentially the same nature—page after page of accurate history bridged up on tiers of learned notes. A statement of Ranke or of Mommsen is capable of mathematical demonstration. Aside from those greater Rankianer, who are all dead except Mommsen, we have a whole brood of *Jungrankianer,* writing biographies, *Staatengeschichte* and theses on isolated ideas. These fill to-day the majority of German professor- and docentships; and history in their hands has reached a scientific accuracy never dreamed of by Gibbon or Niebuhr.

Looked at from one point of view, one would have expected these students and writers to endorse heartily Lamprecht's claim that history is a science. All their efforts, since Ranke's latter years at any rate, had been directed toward that goal; but the author of the new 'Deutsche Geschichte' took them off their feet by cutting asunder all connection between history and its supposed 'makers,' princes and heroes, by putting first and above all the great masses of the people and by making havoc with the Ranke tradition. Instead of seeking the sources of historical information in the greater or smaller European state archives, Lamprecht had diligently studied the Stadt and

Dorf records, the very store accounts of the people. What could have been more revolutionary? In addition to this, history embraces, according to the new comer, all phases of intellectual and physical activity, and not, as the Rankianer believe, only the political side of things. This was not only a sharp reflection on the older school, but a second very practical, if unspoken, declaration that the aristocratic portion of the country should occupy relatively only a few of the pages of history.

Still another cause for complaint of Lamprecht's 'history as a science' is to be found in the latter's approval of the work of the Rankianer as a basis for *Kulturgeschichte,* for a true *Weltgeschichte* which was declared to be a necessary result of the new method. The idea that Ranke and Mommsen had been *preparing* the way for still greater historians was distasteful enough to the Berlin professors—the wearers of the Ranke mantle. Another of Lamprecht's disagreeable claims is that a full and complete list of authorities may be omitted and that the historian's page need not always be securely underpinned with double columns of notes and references. The text itself should embrace the results of the works of individual scholars who have preceded him, should show that the author has compassed the whole field and garnered the fruits of others, but he is not necessarily required to give the names of all the sowers. 'Too many compilations of this kind we have already,' says the Leipzig professor.

Again, Lamprecht's history is based on Darwinism, *i. e.,* it views every element of our present culture world as a result of evolution. Now every follower of Ranke believes in the correctness of Darwin's principal conclusions, and a history which applied these conclusions would have met with their approval but for the fact that it appeared as a sort of criticism of themselves. Emerson's saying that we distrust our own best thoughts until another gives them expression might fitly apply here if he had but added 'but we are usually angered at the one who announces them if they prove popular.' Schopenhauer's protest against idealism, his violent destructiveness, seriously affected the *Weltanschauung* of Ranke historians; then came the Englishman's revolutionary teaching completely superseding the traditional German philosophy, but all to no effect so far as history-writing was concerned. Lamprecht believes the theory of evolution has ceased to be a theory, that it is really the basis of modern thought, and consequently he holds that history must be rewritten, if it is to meet the demands of the time. His 'Deutsche Geschichte' reestablishes the connection between history and philosophy.

A work of such revolutionary character must necessarily meet violent opposition rather than fair criticism. The question which the unbiased student of history asks is: Does the book satisfy the demands of history while answering the requirements of philosophy? Del-

brück, Lenz and Bülow, all of the strictest Ranke sect, answer this question in the negative, and in support of their position they have successfully shown that numerous errors of detail have been made, that in many instances Lamprecht has used the writings of his predecessors without making the customary acknowledgment. Errors of detail in such a work covering, as it does, two thousand years of German history, are to be expected, and they are, if not too serious, readily excusable. This seems to be the case with the 'Deutsche Geschichte' even if we accept all that the Berlin critics claim. The second objection, the use of the writings of his predecessors without making the usual acknowledgments, is not so easily explained away unless one admits Lamprecht's theory, referred to above, that a historical writing of any pretension should embody the best works of the past and interpret them to the reader in the forms of present-day thought, and that it is not incumbent on the historian to give his authority for everything he states. Admitting this, Lamprecht's book meets every requirement of historical criticism and at the same time advances history-writing a long step forward.

One thing is evident, the Rankianer have of late years carried their methods to great extremes, to such extremes that many American students have manifested a disposition to revolt. And their position in Germany is still more untenable. A new man and a new method were needed; Lamprecht met the demand. On the other hand, a better style, a more attractive form of history-writing has long been the prayer of the general public. No one denies that Lamprecht is master of a brilliant style; he is not surpassed in the use of idiomatic German by the celebrated v. Treitschke himself, perhaps the best stylist of the Ranke school.

On the whole, Lamprecht has done a notable work. He has gathered about him more students of history than any other teacher in Europe; he has called into serious question the prevailing methods of studying and writing history; he has given us a book which is exceedingly interesting, which does not seriously violate the rules of the best criticism; and finally, he has almost convinced us that history is a science.

PULSE AND RHYTHM.

BY MARY HALLOCK,
PHILADELPHIA, PA.

THE close connection between pulse and rhythm has been speculated upon since the fourth century before Christ. Herophile, Avicenna, Savonarola, Saxon, Fernel and Samuel Hafen-Refferus have successively conjectured that the rhythmic phenomenon of pulse is in some way responsible for our sense of 'beat.' The speculation was fascinating. It could not become convincing without the help of data capable of being furnished only by very recently invented instruments and by recently accumulated knowledge.

A sense of rhythm, probably due to instinct, is found well developed low down in the animal series.* This fact is significant when one considers that the theory usually advanced and accepted is that physical activities of a regularly recurrent nature have created this sense in man. The beat of the pestle used by primitive man to crush grain, the blows of the flail, the rhythm of the quern and the spinning wheel, the rock of the cradle, and in short the entire series of industries where a regular beat or reciprocal motion suggests alternate action have been put forward as the probable origin of the dance, musical and verbal rhythm, and at length of the beat of music.†

Tempting as is this theory which associates the origin of rhythm with the development of ordered human activity, a rhythmic sound, call or cry is first found coexistent with the first complete circulatory system, heart with valves and blood vessels. This first appears in the insect family and there too, in the saltoria of the orthoptera (commonly known as crickets, grasshoppers and locusts) appears this conjunction of hearing, ability to call or stridulate, a nervous system and valvular heart. The common existence of these phenomena does not prove that the beat of the rudimentary insect heart led to rhythm, but it suggests, at least, that this combination has been subjectively fruitful of recurrent sound as a form of sexual and probably of pleasurable activity.

Mr. S. H. Scudder has put down the songs of these little creatures in musical notation,‡ giving them after careful consideration the attribute of rhythm. Unfortunately the circulatory system of the insect world

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* 'Descent of Man,' Darwin, D. Appleton & Co., p. 566.

† 'Rhythmus und Arbeit.' Karl Bücher, passim.

‡ 'The Songs of the Grasshoppers,' *Am. Nat.*, Vol. II., p. 113.

has scarcely been investigated. As a curiosity, yet as a possible venture, a parallelism may be suggested between the stridulations of a cricket, which have been counted as occurring at the rate of between two and three chirps per second* and the number of pulse waves peculiar to very active insects or one hundred and fifty closures of the heart valves in one minute.†

Inspecting in a very cursory manner the higher phylums of the animal kingdom, the authority of numerous investigators can be given for the perfect rhythmic quality of bird songs. The writer can vouch for it that the cackle of one guinea hen during an entire summer went with clock-like regularity at the rate of eighty-eight to ninety-two cackles per minute. The faster cackling being a laughably accurate sign of the growing excitement attendant on the laying of an egg, said by the owner to occur at about eleven o'clock every morning.

The scientific study of rhythm, so far as man is concerned, has been approached almost wholly from the side of its conjunction with literature. Looked at from that side, it is not strange that the testimony could never be mathematically exact and emphatic. The only data which are of sufficient accuracy to prove that the rhythmic phenomena of pulse first impressed on our consciousness that which can accurately be called rhythm, are to be found in the metronomic denotations of musical compositions. It is there and there only that the brain has been able systematically to externalize the rhythm most natural to it with a sense of method and order approximating instrumental exactitude and capable of an exact expression and measure in number. These furnish only a trace, but a trace sufficient when one keeps in mind the havoc that conscious intellect can always play with things strictly natural.

While making a bibliographical search for anything treating of this musical side of the subject, one suggestive title only was found. It was under 'pulse' in the Larousse Encyclopedia and covered the subject to a degree alarming to a new and anxious investigator. It 'Nouvelle methode facile et curieuse pour connaître le pouls par les notes de la musique.' (New method, easy and curious for gauging the pulse by musical notes.) François Nicolas Marquet, Nancy, 1747. When found, the quaint little book proved lamentably insufficient. In its time there was neither metronome nor sphygmograph.

In the introduction to this little treatise which in its day seems to have created quite a stir—'amateurs in search of novelties bought it for fun, and kept it by good taste,' M. Marquet naïvely tries to disarm his critics by saying that he already seemed to hear them object: 'it is certainly a very bizarre matter this learning to know the pulse by musical notes,' adding, 'one could answer them, it is not more strange

* '*Proc. Boston Soc. Nat. Hist.*, October 23, 1867.

† 'A Text-book of Entomology,' Packard, Macmillan, 1898, p. 401.

to paint the pulse with notes than to paint the sound of music with those same notes; to paint numbers with figures, and finally to paint words with letters.' In this way the good doctor confounds throughout the treatise the idea that music notes and measures could make a very good sign-board on which to denote exactly where a morbid pulse fails of being normal, and his discovery that a minute of his time was usually placed at the same rhythmic rate per minute as accompanies a normal pulse, which pulse, for want of a better chronometer than the long hand of a clock, he places at one beat per second.

This little work, imperfect as it is, and in spite of all its limitations, renders clear, tangible and visible the failure, already mentioned, made by those who thus far have occupied themselves with the question, to give consideration to the statistics furnished by musical compositions through their metronomic denotations. Even the ear aided by the metronome and the pulse recorded by the sphygmograph need to prove the influence of the latter on the former, the unconscious record made in musical composition of the recollection by the mind from an indefinite number of beats per second of a certain stated number, which repeats itself in one form of union after another by different composers at different periods and in different lands.

The material from which statistics can be drawn is so unlimited that, for want of space, two examples only will be considered, the first dealing with the metronomic markings of the Beethoven Sonatas and the second with popular music.

Out of forty-three metronomic markings, taken straight through from the beginning of the first volume of the Beethoven Sonatas—the four standard editions as a working basis—nineteen are set to a rhythm of seventy-two and seventy-six beats to a minute, a rate exactly that of the average normal, healthy, adult human pulse; a pulse given by the best authorities as lying between seventy and seventy-five pulsations in the same time. According to fuller statistics, the physical pulse, varied by the time of day and the effect of meals, ranges from a little below sixty to a little over eighty. Within this limit all the rhythmic markings of these sonatas lie. Three standing at fifty-six and fifty-eight beats per minute, contrary to expectation, belonging to fast movements undoubtedly marked slower on account of the difficulty the fingers would experience in performing the notes as fast as the imagination would direct. The average of the entire one hundred and forty-seven markings given by the four editors, Von Bülow, Steingräber, Köhler and Germer, was sixty-four and four tenths rhythmic beats per minute. The one sonata marked by Beethoven himself bearing the figures 69, 80, 92, 76, 72 for the different movements, Allegro, Vivace, Adagio, Largo, Allegro risoluto.

If with the eye fixed on the second-hand of a watch or a clock the long meter doxology be sung, every one of the equally accented notes entering simultaneously with the tick of each consecutive second, it will become at once apparent that the melody is delivered at a rhythmic rate of sixty beats to the minute. Should one in the same breath hum Yankee-doodle, sounding each of its accented notes, at the same rate, it will be found that these two melodies, standing at the extremes of the sublime and the ridiculous, the one in character slow, the other fast, the first combining the utmost dignity and breadth, the second ludicrously vapid and thoughtless, are both set to precisely the same length of rhythmic time by the clock. In the same manner the adagios, allegros, prestos of the great master's sonatas unfold to pretty much the same span of a passing moment. In his sonata 'Les Adieux,' op. 81, the adagio or slow movement and the allegro or fast movement are both set to one rhythmic unit to the second. The impression of slowness or rapidity in the music is due rather to the character of the context and the number of notes to be played in the divisions within the minute than to the actual clock time it takes to perform the rhythmic unit.

Seventeen letters were addressed to as many band-masters asking them for the 'beat' usually used in their conducting. The answers invariably brought 'from 64 to 72 rhythmic beats per minute,' that being probably the time to which countless soldiers had found it most convenient and agreeable to march. Those wishing to investigate on their own account will find it interesting to clutch at their pulse, whenever a whistling street boy passes, and even a jangling hotel piano might in the same connection have sometimes a 'reason for being.' More often than accident warrants, it will be found that these also 'with nature's heart in tune' were 'concerting harmonies.'

Metronomic Markings per Rhythm of the Different Movements of Twelve Beethoven Sonatas.

Sonata, Op. 2, No. 1.	Sonata, Op. 2, No. 3.	Sonata, Opus 13.	Sonata, Opus 22.	Sonata, Opus 26.	Sonata, Op. 27, No. 2.	Sonata, Op. 31, No. 2.	Sonata, Opus 53.	Sonata, Opus 57.	Sonata, Opus 78.	Sonata, Opus 79.	Sonata, Opus 106.
56	76	66	72	76	60	56	76	76	72	72	69
80	66	72	58	80	76	92	66	58	63	56	80
72	76	60	63	72	76	80	76	76	69	72	92
56	58	52	76	60							76
											72

The foregoing examples, although following the pulse in their exactness, are still for scientific purposes not quite what may be desired. The heart's action varies. So do musical tempi. Both are disturbed by the slightest exciting or nervous influences. Still the track, though faint at times, sometimes quite effaced by conscious effort, is there; corroborated through a hundred different channels. One distinguished psychologist* finds that a subject could repeat simple intervals without accent with greatest exactness when these intervals lay between 0.4 and 0.7 seconds. It takes but a simple problem in arithmetic to see that this agrees with from 75 to 86 rhythmic beats per minute, or the region of pulsation common to the human pulse. Another† on conducting a series of experiments on rhythm, 'the first and most important object of which was to determine what the mind did with a series of simple auditory impressions in which there was absolutely no change of intensity, pitch, quality or tone interval,' finds that the pulse seemed at times to impose a grouping in which the clicks coming nearest to the time of the heart beats were accented.

To Professor Bolton‡ must be given the credit of having successfully found the means by which rhythm can be permanently differentiated from time in music. He says this general principle, arrived at by the same experiments, may be stated: "The conception of a rhythm demands a perfectly regular sequence of impressions within the limits of one second and one hundredth of a second. When a longer interval was introduced into the series, the impressions coming between the long intervals fell together into a group but they did not form an organic unity. There was no pleasure in such a rhythm. Something seemed to be looked for in this longer interval which was wanting." Why?

No matter how slowly one sound follows another, time, as understood in music, can still be a characteristic of the sequence. A clock may strike this minute and not again for an hour, but time is still being measured. A rhythm, however, can be said to exist only when sounds succeed each other so as to fall within the same limited horizon of attention. This differentiation has not to this day been clearly made by authors of musical encyclopedias and dictionaries, they having been satisfied with considering rhythm as simply similar in music to meter in verse.

Bearing these statements in mind, it seems improbable that the mere physical activities and industries of primitive peoples, such as cradle-rocking, spinning and grinding should have been so constantly of one rhythm as to impress accidentally a beat of such uniform variation, extending within fifteen pulsations difference a minute

* 'The Psychology of Rhythm,' *Am. Journ. of Psychol.*, January, 1902.

† *American Journ. Psychol.*, Vol. VI., No. 2.

‡ *Ibid.*

(from 65 to 80) on nearly all musical compositions, nor must it be forgotten, as has been said before, that it is these compositions which furnish the only means by which the human brain could, thanks to the metronome, so accurately and sub-consciously give record to the rhythm most natural to it. This rhythm for physical as well as psychological reasons must, it is submitted, in all probability have been suggested, coordinated and regulated by the phenomenon of pulse. The first and patent objection to this theory will be that we have no conscious cognizance of the arterial beat within us. The objection is however fully met by the well-known law that, 'one unvarying action on the senses fails to give any perception whatever.' For familiar examples, we have no conscious sensory impressions from the whirling of the earth, the weight of the air or the weight of our bodies. Yet, inevitably, the recurrent arterial beat, must have left its record and impress on the unconscious and subliminal brain, guiding and determining the conscious and audible expressions. Nor is it without its supporting proof that where the insect's heart beat is 150 to the minute, the insect's chirp runs to the same speed; and where the human heart beat is 60 to 85 to the minute, human musical rhythm runs within the same limits.

Mr. Fiske says, in his 'Outlines of Cosmic Philosophy,' not only must all motions be rhythmical, but 'every rhythm, great or small, must end in some redistribution, be it general or local, of matter and motion.' It is not probable that a dainty rhythmic wave of color external in character would make its impression on the brain, and the latter in turn remain unaffected by a—relatively speaking—thumping cataract of a pulse impulse. Some disturbance of the brain tissue must occur from this vibration, reaching in course the very portion allotted to music. The basilar artery, the brain's basic artery, feeds the chorda tympani by a direct channel, whereas the rest of the cranial tract is fed by ramifications of its ramifications. The stronger surging is therefore directed against the auditory tract. It may be urged that in that case the brain would know but one rhythm. It might be so were it not that 'the whole cerebral and central nervous organism seems a happy adjustment of fixity of habit not too fixed, and susceptibility not too susceptible.'*

"Perception of time duration is always a process and never a state—for us to perceive five seconds, something must durate five seconds, for us to perceive a year some definite sensation would have to durate a year."†

On these principles, imagining a composer seated quietly at his desk in the act of composition, is it not feasible to suppose that sub-

* Herbert Nichols, *Journ. of Psychol.*, Vol. VI., p. 60.

† *Ibid.*

consciously to himself, and for want of a more intimately sympathetic conductor, a physical metronome was within him deflecting his rhythm to its standard? Contrary to the other arts, music has its birth and being entirely from within the human brain, and from within has been impressed a beat of far more rapid rate than the ictus of the recurrent industries already cited on its musical product. The suggestions all this calls forth are of course unlimited. To one we may give our fancy free rein. Mr. James Huneker in his exhaustive summing up of Chopin's music states that master's favorite metronome sign to be 88 to the minute. As 'people with considerable sensibility of mind and disposition have generally a quicker pulse than those with such mental qualification as resolution and steadiness of temper,' could one consider that the ailing Chopin's pulse helped his rhythmic tendency to 88, while the resolute steady Beethoven's was normal?

The arm of knowledge is long; it needs no yardstick with which to measure the stars. Can it feel the pulse of those who have long since crossed the boundaries that separate this world from the next?

THEORIES OF SLEEP.

By PERCY G. STILES,

UNIVERSITY AND BELLEVUE HOSPITAL MEDICAL COLLEGE.

IT is not easy to define the condition of sleep in terms that will not admit of many exceptions. We readily recognize the states of rest and activity, but where the element of consciousness must be considered we are at once upon uncertain ground. If we think of sleep as an unconscious state, sharply contrasted with waking, we do well to limit our use of the word to the case of man and the most intelligent animals. Sleep in this sense is only to be associated with highly developed nervous systems and its final explanation is to be sought in events taking place in the brain.

Various writers upon the subject of sleep have turned their attention to quite different aspects of the matter. Some have undertaken to show why there is the need of sleep and why the tendency to sleep comes on at the close of each day. These writers have dealt with general or systemic causes. Others have concerned themselves with the cause of the unconscious—or dreaming—state in which the sleeper lies. They have endeavored to suggest intimate and local causes. Since the several theories are thus distinct in their application they are not necessarily mutually exclusive.

Broadly speaking we feel sure that the need of sleep follows from general or local fatigue. During waking hours the decomposition processes of the body doubtless rise above the life-long mean, and sooner or later there must be a compensatory fall below the average. The adaptation of the race to alternating light and darkness has made this rhythmic rise and fall to coincide with day and night—though less rigidly under the artificial conditions of civilized life than in more primitive times.

Fatigue at bottom is a chemical phenomenon, and so the theories of the first class are chemical. When a muscle has been stimulated until it exhibits the well-known signs of fatigue, there are two possible inferences—either this means an exhaustion of fuel substances or an accumulation of poisonous waste. Analogous views have been supported in regard to the chemical changes that lead to sleep. We have had an exhaustion theory advanced by Pflüger and an accumulation theory offered by Preyer.

Pflüger's theory has little experimental evidence in its favor. We know that a bloodless muscle may be subjected to a vacuum and made to part with its free oxygen, but that it is still capable of doing much work and of giving off carbon dioxide. In other words, oxidation may take place in the absence of free oxygen. Of course there is but one reasonable explanation, namely, that there is a store of the element in loose chemical combination. This store in the cells is spoken of as 'intra-molecular' oxygen, and its amount may be supposed to vary between rather wide limits. Pflüger pointed out that during the day, the katabolic processes being above the average, this hoard might be reduced until the lack of it should lead to the depression of functional activity and the suspension of consciousness characteristic of sleep.

Perhaps no one will maintain that this theory is adequate by itself. If there were nothing but intra-molecular oxygen to be considered, we should expect that a day of idleness would leave one fresh and bright at bed-time and that severe exercise for half a day might make a long sleep a pressing necessity. Pflüger's idea seems to explain more readily the sensation of being *tired* than that of being *sleepy,* which is so often quite independent of the other.

The alternative theory is to the effect that the waste-products of metabolism are not fully and promptly removed as they are formed during the day's activities, but gradually clog and poison the system until torpor is induced. The lactic acid produced in muscular contractions is held responsible for a great part of this toxic process. Acidity of the blood produces coma, and whatever reduces its normal alkalinity might be expected to favor sleep. Many objections to this theory suggest themselves. It does not explain why many people are at their best late in the day, nor why the onset of sleep is relatively sudden, nor why we are sleepy in the height of digestion when the blood is most alkaline. It is perhaps less easy to assail it if we suppose that the waste-products in question are not at large in the blood but have accumulated in certain cells, especially of the nervous system. In this case we need not assume a large quantity of these narcotic poisons, but only a peculiar distribution, and we can see why mental work is quite as fatiguing as physical work.

The transition from wakefulness to sleep seems rather abrupt, but is not instantaneous. Motor control is generally lost before sensation, and most people agree that of the avenues of communication with the world without, hearing is the last to be closed. This order of events is reversed in waking, when the alarm-clock or the unwelcome call is heard for an appreciable time before the eyes can be opened or a definite sense of one's situation realized. The sinking into sleep is

favored by the removal of all that may excite either the attention or the reflexes. Darkness, quiet, bodily comfort and mental serenity are therefore sought. Sleep may be prevented by any of the contrary conditions—light, noise, pain or anxiety. When it is necessary to contend against drowsiness, one instinctively seeks objects for attention or sensory stimulation, such as may be secured by taking a slightly uncomfortable position. Evidently sleep presupposes a release of the brain from many stimuli and may be warded off by seeing to it that no such release is granted. There is on record the case of an unfortunate boy who had no cutaneous sensibility, was blind in one eye and deaf in one ear. His mentality was of a low order. To cause him to sleep it was only necessary to cover the serviceable eye and ear for a few moments. Here the waking condition was clearly dependent on an unceasing flow of sensory impulses into the brain. A person of higher intelligence, similarly afflicted, would doubtless sleep much less readily, for trains of thought might keep him awake in default of external stimuli.

The approach of sleep is accompanied by distinct vascular changes. The blood stream is shifting its bed. A most imperious summons to sleep comes from the dryness of the eyes, the sign, probably, of a lessened blood-flow through the tear glands. At the same time the temperature of the skin rises, possibly excepting that of the extremities. There is evidence then of a dilatation of the cutaneous vessels as sleep comes on, and the final passage into unconsciousness is accompanied by a considerable further dilatation. These vascular changes have been nicely gauged by what is known as the plethysmographic method, where the subject lay with one hand and forearm fixed in a glass cylinder filled with water. An increase of blood in the arm displaced water from the cylinder and a delicate recording apparatus showed how this dilatation came on with sleep and passed off with waking. An account of such experiments, of more than technical interest, is that contributed by Dr. W. H. Howell to *The Journal of Experimental Medicine* (Vol. II.).

It is generally inferred that the cutaneous dilatation at once reduces the general blood-pressure and the quantity of blood flowing through the brain, by diverting a large share to the skin. The lowering of pressure has been demonstrated by Brush and Fayerweather; the fact that there is anemia of the brain during sleep has been established by direct observation. An English physiologist, Hill, has been led to believe that the dilatation of blood-vessels that relieves the brain in sleep is not limited to the skin, but shared by the arteries of the digestive tract. That this is so is difficult to prove, but it is suggestive that a heavy meal is followed by a long sleep in the case of the lower animals and often with us by a hard struggle with drowsiness.

Cerebral anemia may be merely a concomitant of sleep, but it has frequently been held to be its immediate cause, the cells having previously been fatigued and suffered a lowering of functional capacity which has made them increasingly susceptible to depressing influences. This is the basis of Howell's theory. He has suggested that the exhaustion of the vaso-motor center is what induces sleep. We know that this center is in tonic activity, sending out impulses which hold the blood-vessels in a state of constriction greater than is natural for them. This tonic activity can only mean constant metabolism in the cells of the center. Furthermore the center is subject to the play of afferent impulses from all parts of the body. It is reflexly spurred to action by every sensory impression through eye or ear. It is called to respond in an appropriate manner to every change of posture or other muscular movement. It does not escape the effects of psychic processes, emotional states. Nothing is more natural than to suppose that the nerve cells of the center become fatigued by this unceasing activity. After the hours that we habitually number in a period of waking it responds less and less readily to the demands made upon it. It begins to lose its grip, so to speak, on the superficial and perhaps the splanchnic vessels. The blood supply to the brain tends to become less and the pressure in its arteries to be reduced. The subjective consequence is drowsiness. If it is resisted by fixing the attention or by exercise, the center rallies temporarily under the spurring, contracting the vessels and turning the tide of blood back into the brain. But the anemia soon returns, and the drowsiness becomes more compelling. When the person lies down, a flood of sensory impulses that have been pouring in from the contracting muscles is suddenly checked. The eyes are closed and the stream of visual impulses ceases. With the withdrawal of this reflex stimulation and the acquiescence of the will the center relaxes still further its hold upon the cutaneous vessels, the blood-flow in the brain becomes more reduced, and unconsciousness comes on. During sleep the vaso-motor center is responsive to stimuli from without as the plethysmographic experiments show. A sufficient stimulus produces waking, and seems to operate by turning back into the brain a sufficient quantity of blood displaced from the contracting vessels of the skin. Such a stimulus must be a strong one in the first hour or two of sleep, but later a much weaker one will answer. Several physiologists have tested the depth of sleep at different hours of the night, judging of it by the height from which a weight must be dropped that the sound of its fall shall arouse the sleeper. All have agreed that the greatest depth of sleep is reached as early as the second hour. According to one writer it becomes steadily more shallow from that time until the end. Others have observed a second, minor deep-

ening toward morning. Many people will agree that their own sensations seem to imply such a second period of comparatively profound sleep.

What we call natural waking in the morning is usually due to some stimulus from without—light or sound—which would not have roused one from the deep sleep of midnight. But the stimulus may come from within, as from the state of certain organs or, curiously enough, from the previous resolution to wake at a certain time, which often operates with something of the compulsion of a hypnotic suggestion. Howell supposes that during sleep the nerve-cells of the vaso-motor center are gradually restored to prime condition and hour by hour become more irritable. So it is easier and easier as time passes to induce the vascular changes that involve waking. Moreover, the recuperated center resumes something of its normal tonic activity before consciousness returns, and so the final step is taken with none of that sense of violence that accompanies a sudden waking from sound sleep. The border-line is likely to be crossed and recrossed several times before the waking state is well established. When one is fairly roused mental activity and the pouring in of sensory impulses keep him from further napping.

Now what peculiar condition can be conceived to exist in the brain during the period of anemia and unconsciousness? What microscopical changes may be supposed to mark the transition from wakefulness to sleep? Oddly enough, the two hypotheses which are extant are quite opposite in character. The first, which has attracted the greater notice, is that of Duval. He has suggested that consciousness depends on the contact of cell-processes in the brain whereby effects are propagated from neurone to neurone. If sensory impulses are to alter consciousness, there must be a pathway for their passage. If a single synapse on the course of such a pathway is rendered impassable, the message from the sense-organ is lost from conscious life. If every sensory path is interrupted at any point between the periphery and the cortex, there must be insensibility as to the outside world and the state of the body. If all motor paths are likewise broken, there can be no voluntary action. If, in the third place, the association paths are also severed, there can be no synthetical processes of thought, no ideation. In short, the brain must lose its individuality by the breaking of connections between its structural elements. If we could suppose that every synapse in the central nervous system might be snapped, and impassable gaps opened between the cells wherever one had been wont to influence another, there must be an end of consciousness, for, in utter isolation, these cells could no longer combine their activities into one whole such as forms the physical basis of psychic

life. A much more local disruption of connection, limited perhaps to the cortex, might be sufficient to explain the subjective condition in sleep. At any rate, Duval's view is that the cortical cells are capable of retracting or extending their processes so as to sever and resume their relation with neighboring elements. Experimental evidence in support of this theory is naturally slight. Wiedersheim has described amœboid movements on the part of cells in the nervous system of a small transparent crab. Of course it is only in such lower forms that the living cells can readily be brought under the microscope. Duval himself suddenly beheaded dogs that were awake and others in anæsthesia and made histological preparations from the brains. He believed he could distinguish the sleeping brain by the more contracted and isolated appearance of its cells.

The second histological theory of sleep, which has been said to be quite opposed to the first, is that of the Italian neurologist, Lugaro. Both demand the capability of amœboid movement on the part of the cells. But while Duval supposes that in sleep the cells have broken their contacts, Lugaro supposes that they have made *new contacts* with great freedom. At first thought this view seems unreasonable. A multiplicity of contacts and added pathways in the brain might be supposed to imply a richer and keener consciousness. But this would be true only to a certain point. When the indiscriminate combination had gone a step further mental confusion might be expected, then fantastic associations and a meaningless mosaic of memories—practically a state of dreaming. Let the cells commingle their impulses still more freely and consciousness will be lost, for the diffusion of energy in the brain will result in a lessened intensity of flow in the principal channels. If each cell scatters its communications in every possible direction no definite effect in consciousness is to be looked for. According to Duval, the cells which are affected in sleep can not discharge; according to Lugaro, they may do so, but the resulting impulses are utterly dissipated in a maze of by-ways. Waking, according to Duval, is the resumption of intercourse among these cells; according to Lugaro, it is the restriction of intercourse to habitual and purposeful channels.

There is no reason why we may not be eclectic in regard to these two points of view. It may be that many paths are interrupted in sleep, while others are opened. In the hypnotic state it is clear that many paths are blocked, including those by which the will of the subject habitually asserts itself, while others, especially those making connections between the auditory and motor areas, transmit impulses with extraordinary efficiency. This condition is explicable if we suppose that certain synapses are broken, as Duval imagines, and that

the tide of nervous impulses pours with intensified energy through the narrowed outlets remaining—an idea borrowed from Lugaro. If we consider that a man is most thoroughly awake when his attention is most rigidly concentrated, when he is a 'man of one idea,' we shall perhaps incline toward Lugaro's conception of sleep, which is certainly as far as possible removed from this mental fixedness. Hypnosis is accompanied by cerebral congestion and natural sleep by anemia. There is accordingly a strong temptation to suppose that the cell-changes in the two states are opposite in their nature, that in hypnosis the retraction of the dendrites is characteristic and in natural sleep their extension. The sluggish condition of the mind under suggestion as compared with its fanciful flights in dreaming falls happily in line with this view. But such speculation is premature.

It was said at the outset that the several theories of sleep are not all mutually exclusive. It is possible to go beyond this statement, for we may assign a place to each of those mentioned without inconsistency. We may suppose in the first place that the alternation of day and night through the ages has impressed its rhythm upon the race, so that it is hard for the individual to break from the habitual course in which activity is associated with light and rest with darkness. In other words, the amount of the metabolism tends to keep above a mean for some hours and then to fall below it. The excess of destructive processes over those which are recuperative during the waking hours results in general and local fatigue, a condition into which may enter both the depletion of intra-molecular oxygen and the accumulation of toxic waste-products. While this progressive loss of condition affects the body as a whole, the nervous system is subject to its own peculiar drains. It is very probably the hard-worked vasomotor center which proves to be the vulnerable spot. With its release of the blood-vessels in certain areas from its reenforcing influence comes the cerebral anemia. Then, we may suppose, the nerve-cells become less active than in the brain which has its full supply of blood, that they cease to send impulses over the usual routes, either because gaps have opened or because such impulses as do arise are permitted to stray and be scattered, producing no effect in consciousness or one which is quite bizarre and meaningless.

Such an outline as this is a composite scheme in which the conditions emphasized by Pflüger and Preyer are given recognition as fundamental causes of sleep, Howell's idea is accepted as explaining well its onset, its varying depth and the awakening, while the pictures sketched by Duval and Lugaro are combined to represent the intimate state of the slumbering brain.

HERTZIAN WAVE WIRELESS TELEGRAPHY. IV.

By Dr. J. A. FLEMING, F.R.S.,

PROFESSOR OF ELECTRICAL ENGINEERING IN THE UNIVERSITY COLLEGE, LONDON.

WE have to consider in the next place the arrangements of the receiving station and the various forms of receivers that have been devised for effecting telegraphy by Hertzian waves. Just as the transmitting station consists essentially of two parts, viz., a part for creating electrical oscillations and a part for throwing out or radiating electric waves, so the receiving station appliances may be divided into two portions; the function of one being to catch up a portion of the energy of the passing wave, and that of the other to make a record or intelligible signal in some manner in the form of an audible or visible sign.

Accordingly, there must be at the receiving station an arrangement called a receiving aerial, which in general takes the form of a long vertical wire or wires, similar in form to the transmitting aerial. There is, however, a distinct difference in the function of the transmitting aerial and the receiving aerial. The function of the first is effective radiation, and for this purpose the aerial must have associated with it a store of energy to be released as wave energy; but the function of the receiving aerial is to be the seat of an electromotive force which is created by the electric force and the magnetic force of the incident electric wave.

In tracing out the mode of operation of the transmitting aerial, it was pointed out that the electric waves emitted consisted of alternations of electric force in a direction which is perpendicular to the surface of the earth, and magnetic force parallel to the surface of the earth. These two quantities, the electric force and the magnetic force, are called the *wave vectors,* and they both lie in a plane perpendicular to the direction in which the wave is traveling and at right angles to one another, the electric force being perpendicular to the surface of the earth. In optical language, the wave sent out by the aerial would be called a plane polarized wave, the plane of polarization being parallel to the magnetic force. Hence, if at any point in the path of the wave we erect a vertical conductor, as the wave passes over it, it is cut transversely by the magnetic force of the wave and longitudinally by the electric force. Both of these operations result in the creation of an alternating electro-motive force in the receiving aerial wire.

As in all other cases of oscillatory motion, the principle of resonance may here be brought into play to increase immensely the amplitude of the current oscillations thereby set up in the receiving aerial. As already explained, any vertical insulated wire placed with its lower end near the earth has capacity with respect to the earth, and it has also inductance, the value of these factors depending on its shape and height. Accordingly, it has a natural electrical time-period of its own, and if the periodic electromotive impulses which are set up in it by the passage of the waves over it agree in period with its own natural time-period, then the amplitude of the current vibrations in it may become enormously greater than when there is a disagreement between these two periods. Before concluding these articles we shall return to this subject of electric resonance and syntony, and discuss it with reference to what is called the tuning of Hertzian wave stations. Meanwhile, it may be said that for the sake of obtaining, at any rate in an approximate degree, this coincidence of time-period, it is generally usual to make the receiving aerial as far as possible identical with the transmitting aerial. If the receiving aerial is not insulated, but is connected to the earth at its lower end through the primary coil of an oscillation transformer, we can still set up in it electrical oscillations by the impact on it of an electric wave of proper period; and if the oscillation transformer is properly constructed we can draw from its secondary circuit electric oscillations in a similar period.

One problem in connection with the design of a receiving aerial is that of increasing its effective length and capacity, so as to increase correspondingly the electromotive force or current oscillations in it. It is clear that if we put a number of receiving wires in parallel so that each one of them is operated upon by the wave separately, although we can increase in this way the magnitude of the alternating current which can be drawn off from the aerial, we cannot increase the electromotive force in it except by increasing the actual height of the wires. Unfortunately, there is a limit to the height of the receiving aerial. It has to be suspended, like the transmitting aerial, from a mast or tower, and the engineering problem of constructing such a permanent supporting structure higher than, say, two hundred feet, is a difficult one.

Since any one station has to send as well as receive, it is usual to make one and the same aerial wire or wires do double duty. It is switched over from the transmitting to the receiving apparatus, as required. This, however, is a concession to convenience and cost. In some respects it would be better to have two separate aerials at each station, the one of the best form for sending, and the other of the best form for receiving.

In Mr. Marconi's early arrangements, the so-called coherer or

sensitive wave-detecting appliance, to be described more in detail presently, was inserted between the base of the insulated receiving aerial and the earth, but it was subsequently found by him to be a great improvement to act upon the receiving device, not directly by the electromotive force set up in the aerial, but by the induced electromotive force of a special form of step-up oscillation transformer he calls a 'jigger,' the primary circuit of which was inserted in between the receiving aerial and the earth plate, and the secondary circuit was connected to the sensitive organ of the telegraphic receiving arrangements.* A suggestion to employ transformed oscillations in affecting a coherer, had also been described in a patent specification by Sir Oliver Lodge, in 1897, but the essence of success in the use of this device is not merely the employment of a transformer, but of a transformer constructed specially to transform electrical oscillations.

Turning then to the consideration of the relation existing between the transmitting and receiving aerials, we note that in their simplest form these consist of two similar tall rods of metal placed upright, with their feet in good connection with the earth at two places. We may think of them as two identical lightning conductors, well earthed at the bottom, and supported by non-conducting masts or towers. These rods must be in good connection with the earth, and therefore with it form, as it were, one conductor. If, as usual, these aerials are separated by the sea, the intermediate portion of this circuit is an electrolyte. The operations which take place when a signal is sent are as follows:

At the transmitting station, we set up in the transmitting aerial electric oscillations, of which the frequency may be of the order of a million, *i. e.*, the oscillations as long as they last are at the rate of a million a second. Each spark discharge at the transmitter results, however, only in the production of a train of a dozen or two oscillations, and these trains succeed each other at a rate depending upon the transmitting arrangements used. Each oscillation in the transmitting aerial is accompanied by the detachment from it of semi-loops of electric strain, as already explained. The alterations of electric strain directed perpendicularly to the earth, and of the associated magnetic force parallel to the earth, constitute an electric wave in the ether, just as the alternations of pressure and motion of air molecules constitute an air wave. Associated with these physical actions above

* The term 'jigger' is one of those slang terms which contrive to effect a permanent attachment to various arts and crafts. Similarly, the word 'booster' is now used for a step-up or voltage-raising transformer or dynamo, inserted in series with an electric supply main. The word 'boost' is a slang term signifying to raise or lift up. 'To give a real good boost' is an expression for lending a helping hand. The term 'jigger,' in the same manner, is an adaptation of seaman's term for hoisting tackle or lift.

ground, there is a propagation through the earth of electric action, which may consist in a motion or atomic exchange of electrons. Each change or movement of a semiloop of electric strain above ground has its equivalent below ground in inter-atomic exchanges or movements of the electrons, on which the ends of these semi-loops of electric strain terminate. The earth must play therefore a very important part in so-called 'wireless telegraphy,' and we might almost say the earth does as much as the ether in its production.

The function of the receiving aerial is to bring about a union between these two operations above and below ground. When the electric waves fall upon it, they give rise to electromotive force in the receiving aerial, and therefore produce oscillations in it which, in fact, are electric currents flowing into and out of the receiving aerial. We may say that the transmitting aerial, the receiving aerial and the earth form one gigantic Hertz oscillator. In one part of this system, electric oscillations of a certain period are set up by the discharge of a condenser and are propagated to the other part. In the earth, there is a propagation of electric oscillations; in the space above and between the aerials, there is a propagation of electric waves. The receiving aerial *feels* therefore what is happening at the distant aerial and can be made to record it.*

We have next to consider the question of the wave detecting devices which enable us to appreciate and record the impact of a wave or wave train against the aerial. At the very outset it will be necessary to coin a new word to apply generally to these appliances. Most readers are probably familiar with the term 'coherer,' which was applied by Sir Oliver Lodge, in the first instance, to an electric wave-detecting device of one particular kind, viz., that in which a metal point was lightly pressed against another metal surface and caused to stick to it when an electric wave fell upon it. As our knowledge increased, it was found that there were many cases in which the effect of the electric radiation was to cause a severance and not a coherence, and hence such clumsy phrases as 'anticoherer' and 'self-decohering coherer' have come into use. Moreover, we have now many kinds of electric wave detectors based on quite different physical principles. At the risk of incurring reprobation for adding to scientific nomenclature, the author ventures to think that the time has arrived when a simple and inclusive term will be found useful to describe all the devices, whatever their nature, which are employed for detecting the presence of an electric wave. For this purpose the term *kumascope*, from the Greek κῦμα (a wave), is suggested. The scientific study of waves has already been called

* The 'earth' itself probably only conducts electrolytically. All such materials as sand, clay, chalk, etc., and most surface soils are fairly good insulators when very dry, but conduct in virtue of moisture present in them.

kumatology, and in view of our familiarity with such terms as *microscope, electroscope* and *hygroscope,* there does not seem to be any objection to enlarging our vocabulary by calling a wave-detecting appliance a *kumascope.* We are then able to look at the subject broadly and to classify kumascopes of different kinds.

We may, in the first place, arrange them according to the principle on which they act. Thus, we may have electric, magnetic, thermal, chemical and physiological operations involved; and finally, we may divide them into those which are self-restoring, in the sense that after the passage or action of a wave upon them they return to their original sensitive condition; and those which are non-restoring, in that they must be subjected to some treatment to bring them back again to a condition in which they are fit to respond again to the action of a wave.

We have no space to refer to the whole of the steps of discovery which led up to the invention of all the various forms of the modern electric kumascope or wave detector. Suffice it to say that the researches of Hertz in 1887 threw a flood of light upon many previously obscure phenomena, and enabled us to see that an electric spark, and especially an oscillatory spark, creates a disturbance in the ether, which has a resemblance in nature to the expanding ripples produced by a stone hurled into water. Scientific investigation then returned with fresh interest to previously incomprehensible effects, and a new meaning was read into many old observations. Again and again it had been noticed that loose metallic contacts, loose aggregations of metallic filings or fragments, had a mysterious way of altering their conductivity under the action of electric sparks, lightning discharges and high electromotive forces.

As far back as 1852, Mr. Varley had noticed that masses of powdered metals had a very small conductivity, which increased in a remarkable way during thunderstorms;* and in 1866, C. and S. A. Varley patented a device for protecting telegraphic instruments from lightning, which consisted of a small box of powdered carbon in which were buried two nearly touching metal points, and they stated that 'powdered conducting matter offers a great resistance to a current of moderate tension, but offers but little resistance to currents of high tension.'†

We then pass over a long interval and find that the next published account of similar observations was due to Professor T. Calzecchi-Onesti, who described in an Italian journal, *Il Nuovo Cimento* (see Vol. 16, p. 58, and Vol. 17, p. 38), in 1884 and 1885 his observations on the decrease in resistance of metal powders when the spark from an

* *The Electrician*, Vol. XL., p. 86 (Leader).

† *British Patent Specification*, C. and S. A. Varley, No. 165, 1866.

induction coil was sent through them.* These observations did not attract much attention until Professor E. Branly, of Paris, in 1890 and 1891, repeated them on an extended scale and with great variations, making the important observation that an electric spark *at a distance* had a similar effect in increasing the conductivity of metallic powders.† Branly, however, noticed that in some cases of conductors in powder, such as the peroxide of lead or antimony, the effect of the spark was to cause a decrease of conductivity.

To Professor E. Branly unquestionably belongs the honor of giving to science a new weapon in the shape of a tube containing metallic filings or powder rather loosely packed between metal plugs, and of showing that when the pressure on the powder was adjusted such a tube may be a conductor of very high resistance, but that the electrical conductivity is enormously increased if an electric spark is made in its neighborhood. He also proved that the same effect occurred in the case of two slightly oxidized steel or copper wires laid across one another with light pressure, and that this loose or imperfect contact was extraordinarily sensitive to an electric spark, dropping in resistance from thousands of ohms to a few ohms when a spark was made many yards away.

It is curious to notice how long some important researches take to become generally known. Branly's work did not attract much attention in England until 1892, when Dr. Dawson Turner described his own repetition of Branly's experiments with the metallic filings tube, at a meeting of the British Association in Edinburgh. In the discussion which followed, Professor George Forbes made an important remark. He asked whether it was possible that the decrease in resistance could be brought about by Hertz waves.‡

This question shows that even in 1892 the idea that the effect of the spark on the Branly tube was really due to Hertzian waves was only just beginning to arise. The following year, however, Mr. W. B. Croft repeated Branly's experiment with copper filings before the Physical Society of London, and entitled his short paper 'Electric Radiation on Copper Filings.'§ He exhibited a tube containing copper filings loosely held between two copper plugs and joined in series with a galvanometer and cell. The effect of an electric spark at a distance, in causing increase of conductivity, was shown, and the return of the tube to its non-conducting state when tapped was also noticed.

* See also *Journal de Physique*, Vol. V., p. 573, 1886.

† See *Comptes Rendus*, Vol. CXI., p. 785; Vol. CXII., p. 112, 1891; or *La Lumière Electrique*, Vol. XL., pp. 301, 506, 1891; or *The Electrician*, Vol. XXVII., 1891, pp. 221, 448.

‡ See *The Electrician*, Vol. XXIX., 1892, pp. 397 and 432.

§ Mr. W. B. Croft, *Proc. Phys. Soc.*, Vol. XII., p. 421. Report of meeting on October 27, 1893.

In the discussion which followed the reading of this paper, Professor Minchin described the effects of electric radiation on his impulsion cells. He followed up this by reading a paper to the Physical Society on November 24, 1893, on the action of Hertzian radiation on films containing metallic powders, and expressed the opinion that the change in resistance of the Branly tube was due to electric radiation.*

Thus, at the end of 1893, a few physicists clearly recognized that a new means had been given to us for detecting those invisible ether waves, the chief properties of which Hertz had unraveled with surpassing skill six years before, by means of a detecter consisting of a ring of wire having a small spark gap in it.

In June, 1894, Sir Oliver Lodge delivered a discourse at the Royal Institution, entitled 'The Work of Hertz,' and at this lecture use was made of the Branly tube as a Hertz wave detecter. The chief object of the lecture was to describe the properties of Hertzian waves and their reflection, absorption and transmission, and many brilliant quasi-optical experiments were exhibited. Although a Branly tube, or imperfect metallic contact, then named by him a *coherer,* was employed by Sir Oliver Lodge to detect an electric wave generated in another room, there was no mention in this lecture of any use of the instrument for telegraphic purposes.†

As we are here concerned only with the applications in telegraphy, we shall not spend any more time discussing the purely scientific work done with laboratory forms of this wave detector.

Without attempting to touch the very delicate question as to the precise point at which laboratory research passed into technical application, we shall briefly describe the forms of kumascope which have been devised with special reference to Hertzian wave telegraphic work. A very exact classification is at present impossible, but we may say that telegraphic kumascopes may be roughly divided into six classes. The first class includes all those that depend for their action on the 'coherer principle' or the reduction of the resistance of a metallic microphone by the action of electromotive force. As they depend upon an imperfect contact, they may be called *contact kumascopes.* This class is furthermore subdivided into the self-restoring and the non-self-restoring varieties. The second class comprises the *magnetic kumascopes*

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* See Professor Minchin, *Proc. Phys. Soc.*, November 24, 1893; or *The Electrician*, Vol. XXXII., 1893, p. 123. See also Professor Minchin, *Phil. Mag.*, January, 1894, Vol. 37, p. 90, 'On the Action of Electromagnetic Radiation on Films containing Metallic Powders.'

† This lecture was afterwards published as a book, the first edition bearing the same title as the lecture, *viz.*, 'The Work of Hertz and Some of his Successors.' In the second edition, published in 1898, an appendix was added (p. 59) containing 'The History of the Coherer Principle,' and the original title of the work had prefixed to it, 'Signalling without Wires.'

which depend upon the action of an electrical oscillation as a magnetizing or demagnetizing agency. The third class comprises the *electrolytic responders,* in which the action of electric oscillations either promotes or destroys the results of electrolysis. The fourth class consists of the *electrothermal detectors,* in which the power of an electrical oscillation as a high frequency electric current to heat a conductor is utilized. The fifth class comprises the *electromagnetic* or *electrodynamic* instruments, which are virtually very sensitive alternating current ammeters, adapted for immensely high frequency. The sixth class must be made to contain all those which cannot be well fitted at present into any of the others, such as the sensitive responder of Schäfer, the action of which is not very clearly made out.

We may proceed briefly to describe the construction of the principal forms of kumascope coming under the above headings. In the first place, let us consider those which are commonly called the 'coherers' or, as the writer prefers to call them, the *contact kumascopes.* The simplest of these is the crossed needle or single contact, which originated with Professor E. Branly.* The pressure of the point of a steel needle against an aluminium plate was subsequently found by Sir Oliver Lodge to be a very sensitive arrangement when so adjusted that a single cell sends little or no current through the contact.† When an electric wave passes over it, good conducting contact ensues. The point is, in fact, welded to the plate, and can only be detached by giving the plate or needle a light shock or vibration. A variation of the above form is a pair of crossed needles, one resting on the other.

Professor Branly found, in 1891, that if a pair of slightly oxidized copper wires rest across one another the contact resistance may fall from 8,000 to 7 ohms by the impact of an electric wave. He has recently devised a tripod arrangement, in which a light metal stool with three slightly oxidized legs stands on a polished plate of steel. The contact points must be oxidized, but not too heavily, and the stool makes a bad electrical contact until a wave falls upon it.‡ The decoherence is effected by giving the stool a tilt by means of an electromagnet.

These single or multiple point kumascopes labor under the disadvantage that only a very small current can be passed through the variable contact when used as a relay arrangement, without welding them together so much that a considerable mechanical shock is required to break the contact and reset the trap.

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* See *The Electrician,* Vol. XXVII., 1891, p. 222. E. Branly, 'Variations of Conductivity under Electrical Influence.'

† See *The Electrician,* Vol. XL., p. 90. Sir Oliver Lodge, 'The History of the Coherer Principle.'

‡ See Professor E. Branly, 'A Sensitive Coherer,' *Comptes Rendus,* Vol. CXXXIV., p. 1187, 1902; or *Science Abstracts,* Vol. V., p. 852, 1902.

The logical development of the single contact is therefore the infinite number of contacts existing in the tube of metallic filings, which has been the form of kumascope most used for many years. In its typical form it consists of a tube of insulating material with metallic plugs at each end, and between them a mass of metallic powder, filings, borings, granules or small spheres, lightly touching one another. Imperfect contact must be arranged by light pressure, and in the majority of cases the resistance is very large until an electric wave falls upon the tube, when it drops suddenly to a small value and remains there until the tube is given a slight shake or the granules disturbed in any way, when the resistance suddenly rises again. This type of responder is a non-restoring kumascope, and requires the continual operation of some external agency to keep it in a condition in which it is receptive or sensitive to electric waves.

Much discussion and considerable research have taken place in connection with the action and improvement of these metallic powder kumascopes. As regards materials, the magnetic metals, nickel, iron and cobalt, in the order named, appear to give the best results. The noble metals, gold, silver and platinum, are too sensitive, and the very oxidizable metals too insensitive, for telegraphic work, but an admixture may be advantageously made.

Omitting the intermediate developments of invention, it may be said that Mr. Marconi was the first to recognize that to secure great sensibility in an electric wave detecter of this type the following conditions must be fulfilled: An exceedingly small mass of metallic filings must be placed in a very narrow gap between two plugs, the whole being contained in a vessel which is wholly or partly exhausted of its air. Mr. Marconi devoted himself with great success to the development of this instrument, and in a very short time succeeded in transforming it from an uncertain laboratory appliance, capable of yielding results only in very skilled hands, into an instrument certain and simple in its operations as an ordinary telegraphic relay. He did this, partly by reducing its size, and partly by a most judicious selection of materials for its construction. As made at present, the Marconi metallic filings tube consists of a small glass tube, the interior diameter of which is not much more than one eighth of an inch, which has in it two silver plugs which are beveled off obliquely. These are placed opposite to each other so as to form a wedge-shaped gap, about a millimeter in width at the bottom and two, or at most three, millimeters in width at the top (see Fig. 1). The silver plugs exactly fill the aperture of the tube, and are connected to platinum wires sealed through the glass. The tube has a lateral glass tube fused into it, by which the exhaustion is made, which is afterwards sealed off, and this tube projects on the side of the wider portion of the gap between the

silver plugs. The sensitive material consists of a mixture of metallic filings, five per cent. silver and ninety-five per cent. nickel, being carefully mixed and sifted to a certain standard fineness. In the manufacture of these tubes, great care is taken to make them as far as possible absolutely identical. Each tube when finished is exhausted, but not to a very high vacuum. The tube so finished is attached to a bone holder, by which it can be held in a horizontal position. The object of beveling off the plugs in the Marconi tube is to enable the sensitiveness of the tube to be varied by turning it round, so that the small quantity of filings lie in between a wider or narrower part of the gap.*

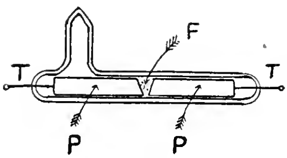

FIG. 1. MARCONI SENSITIVE TUBE OR METALLIC FILINGS KUMASCOPE. *PP*, silver plugs; *TT*, platinum wires; *F*, nickel and silver filings.

Other ways of adjusting the quantity of the filings to the width of the gap have been devised. Sometimes one of the plugs is made movable. In other cases, such as the tubes devised by M. Blondel and Sir Oliver Lodge, there is a pocket in the glass receptacle to hold square filings, from which more or less can be shaken into the gap.

An interesting question, which we have not time to discuss in full, is the cause of the initial coherence of the metallic filings in a Branly tube. It does not seem to be a simple welding action due to heat, and it certainly takes place with a difference of potential, which is very far indeed below that which we know is required to produce a spark. On the other hand, it seems to be proved that in a Branly tube, when acted upon by electric waves, chains of metallic particles are produced. The effect is not peculiar to electric waves. It can be accomplished by the application of any high electromotive force. Thus, Branly found that coherence may be produced by the application of an electromotive force of twenty or thirty volts, operating through a very high water resistance and thus precluding the passage of any but an excessively small current. Again, the coherence seems to take place in some cases when metallic particles are immersed in a liquid, or even in a solid, insulator. Professor Branly has therefore preferred to speak of masses of metallic granules as *radio-conductors,* and Professor Bose has divided substances into positive and negative, according as the operation of electromotive force is to increase the coherence of the particles or to decrease it.

It has been asserted that for every particular Branly tube, there is a critical electromotive force, in the neighborhood of two or three volts, which causes the tube to break down and pass instantly from a non-

* This device of making the inter-electrode gap in a tubular filings coherer wedge-shaped has been patented again and again by various inventors. See German patent No. 116,113, Class 21a, 1900. It has also been claimed by M. Tissot.

conductive to a conductive condition, and that this critical electromotive force may become a measure of the utility of the tube for telegraphic purposes. Thus, C. Kinsley (*Physical Review*, Vol. XII., p. 177, 1901) has made measurements of this supposed critical potential for different 'coherers,' and subsequently tested the same as receivers at a wireless telegraph station of the U. S. A. Signal Corps. The average of twenty-four experiments gave in one case 2.2 volts as the breaking down potential of one of these coherers or Branly tubes, 3.8 volts for a second and 5.5 volts for the third. These same instruments, tested as telegraphic kumascopes, showed that the first of the three was most sensitive.

On the other hand, W. H. Eccles (*Electrician*, Vol. XLVII., pp. 682 and 715, 1901) has made experiments with Marconi nickel-silver sensitive tubes, using a liquid potentiometer made with copper sulphate, to apply the potential so that infinitesimal spark contacts might be avoided and the changes in potential made without any abruptness. He states that if the coherer tube is continuously tapped, say at the rate of fifty vibrations per second, whilst at the same time an increasing potential is applied to its terminals and the current passing through it measured on a galvanometer, there is no abrupt change in current at any point. He found that when the current and voltage were plotted against each other, a regular curve was obtained, which after a time becomes linear. A decided change occurs in the conductivity of the mass of metallic filings when treated in this manner at voltages lower than the critical voltage obtained by previous methods. He ascertained that there was a complete correspondence between the sensitiveness of the tubes used as telegraphic instruments and the form of the characteristic curve of current and voltage drawn by the above described method.

In the same manner, K. E. Guthe and A. Trowbridge (*Physical Review*, Vol. II., p. 22, 1900) investigated the action of a simple ball coherer formed of half a dozen steel, lead or phosphor-bronze balls in slight contact. They measured the current i passing through the series under the action of a difference of potential v between the ends, and found a relation which could be expressed in the form

$$v = V\,(1 - e^{\,ki})$$

where V and k are constants.

The current through this ball coherer is therefore a logarithmic function of the potential difference between its ends, of the form

$$i = a \log\,(v - V)$$

and exhibits no discontinuity.

The inference was drawn that the 'resistance' is due to films of

water adhering to the metallic particles through which electrolytic action occurs.

A good metallic filings tube for use as a receiver in Hertzian wave telegraphy should exhibit a constancy of action and should cohere and decohere, to use the common terms, sharply, at the smallest possible tap. It should not have a current passed through it by the external cell of more than a fraction of a milliampere, or else it becomes wounded and unsensitive.

The investigations which have already taken place seem to show pretty clearly that the agency causing the masses of filings to pass from a non-conductive to a conductive condition is electromotive force, and that therefore it is the electromotive force set up in the aerial by the incident waves which is the effective agent in causing the change in the metallic filings tube, when this is used as a telegraphic kumascope. This transformation of the tube from a non-conductor to a conductor is made to act as a circuit-closer, completing the circuit, by means of which a single cell of a local battery is made to send current through an ordinary telegraph relay, and so by the aid of a second battery operate a telegraphic printer or recorder of any kind. Hence, it is clear that after one impact, the metallic filings tube has to be brought back to its non-conductive condition, and this may be achieved in several ways. (1) By the administration of carefully regulated taps or shocks or by rotating the tube on its axis; (2) by the aid of an alternating current; (3) in those cases where filings of magnetic metals are employed, by magnetism.

The decoherence by taps was discovered by Branly,* and Popoff, following the example of Sir Oliver Lodge, employed an electric bell arrangement for this purpose.†

Mr. Marconi, in his original receiving instruments, placed an electromagnet under the coherer tube with a vibrating armature like an electric bell.‡ This armature carries a small hammer or tapper, which, when set in action, hits the tube on the under side, and various adjusting screws are arranged for regulating exactly the force and amplitude of the blows. This tapper is actuated by the same current as the Morse printer, or other telegraphic recorder, so that when the signal is received and the metallic filings tube passes into the conductive condition and closes the relay circuit, this latter in turn closes the circuit of the Morse printer or other recorder, and, at the same time, a current passes through the electromagnet of the tapper and the tube is tapped back. This sequence of operations requires a certain

* See *The Electrician*, Vol. XXVII., 1891, p. 448.

† Journal of *The Russian Physical and Chemical Society*, Vol. XXVIII.; division of physics, Part I., January, 1896.

‡ See Brit. Patent Specification, No. 12,039, June 2, 1896.

time which limits the speed of receiving. The tapper has to be so arranged that it is possible to receive and to record not only the *dot* but a *dash* on the Morse system. The *dash* is really a series of closely adjacent dots, which run together in virtue of the inertia and inductance of the different parts of the whole receiving apparatus. The adjustment has so to be made that, whilst the *dash* is being recorded and a continuous tapping is kept up, yet, nevertheless, the continued electromotive force in the aerial, due to the continually arriving trains of waves, is able to act against the tapping and to keep the filings in the tube in the conductive condition. Hence, the successful operation of the arrangement requires attention to a number of adjustments, but these are not more difficult, or even as difficult, as those involved in the use of many telegraphic receivers employed in ordinary telegraphy with wires.

Mr. Marconi also introduced devices for preventing the sparks at the contacts of the electromagnetic hammer from directly affecting the tube, and also to prevent the electric oscillations which are set up in the aerial from being partly shunted through other circuits than that of the sensitive tube. We pass on to notice the remaining devices for restoring the metallic filings tube to a condition of sensitiveness or receptiveness.

A method for doing this by alternating currents is due to Mr. S. G. Brown.* The pole pieces of the coherer tube are made of iron, and they are enveloped in magnetizing coils traversed by an alternating electric current. Between these pole pieces is placed a small quantity of nickel or iron filings, and under the action of the electromotive force, due to an electric wave acting on them, may be made to cohere in the usual fashion; but the moment that the wave ceases, the alternating magnetism of the electrodes causes the filings to drop apart or decohere. In place of the alternating current, Mr. Brown finds that a revolving permanent magnet can be used to produce the alternating magnetization of the pole pieces of the sensitive tube or coherer.

The third method of causing the decoherence of the filings is that due to T. Tommasina. He found that when a Branly tube is made with filings of a magnetic metal, such as iron, nickel and cobalt, the decoherence of the filings can be produced by means of an electromagnet placed in a suitable position under the tube.† The explanation of this fact seems to be that, when an electric wave falls upon the tube or when any other source of electromotive force acts upon it, chains of metallic particles are formed, stretching from one electrode

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* British Patent Specification, No. 19,710 of 1899.

† *Comptes Rendus*, Vol. CXXVIII., p. 1225, 1889; *Science Abstracts*, Vol. II., p. 521.

to the other. Tommasina contends that he has proved the existence of these chains of particles by experiments made with iron filings; and R. Malagoli,* in referring to Tommasina's assertion, states that it can be witnessed in the case of brass filings placed between two plates of metal and immersed in vaseline oil, when a difference of potential is made between the plates.

T. Sundorph† says he has confirmed Tommasina's discovery of the formation of these chains of metallic particles in the coherer. The filings do not all cling together, but certain chains are formed which afford a conducting path for the current subsequently passed through the coherer from an external source. Accordingly, Tommasina's method of causing decoherence in the case of filings of magnetic metals is to pull them apart by an external magnetic field; and he stated that decoherence can be effected more easily and regularly in this way than by tapping. Whilst on this point, it may be mentioned that C. Tissot‡ says that he has found that the sensitiveness of a coherer formed of nickel and iron filings can be increased by placing it in the magnetic field, the lines of which are parallel to the axis of the tube. According to MM. A. Blondel and G. Dobkevitch, this is merely the result of an increased coherence of the particles.

(To be continued.)

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* *Il Nuovo Cimento*, Vol. X., p. 279, 1899.

† *Wied. Ann.*, Vol. LXVIII., p. 594, 1899; *Science Abstracts*, Vol. II., p. 757.

‡ *Comptes Rendus*, Vol. CXXX., p. 902, 1900; *Science Abstracts*, Vol. III., p. 615.

MOSQUITOES AND SUGGESTIONS FOR THEIR EXTERMINATION.*

By WILLIAM LYMAN UNDERWOOD,

LECTURER IN THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

THE statement has been frequently made of late that there is no more reason why we should suffer from mosquitoes than there is that we should allow rats and mice to continually annoy us, and this statement is in a measure true. Rats and mice are to a great extent effectively held in check; for we have become accustomed to them and their habits, and we know how to deal with them. Were it not for the fact that a constant warfare is being waged against them, they would soon overrun our houses and make life unbearable.

In order to fight the mosquitoes successfully it is important that every one should take an interest in the popular uprising against this insect pest. And now that it is known that, besides being a nuisance, mosquitoes may be a menace to the health of the community, it is equally necessary that every one should become familiar with all that pertains to their life history so that the war against them may be successfully and intelligently carried on. Notwithstanding all that has been written on the subject of mosquitoes, during the last year or two, the majority of people still know but little about them.

It is the purpose of this article to state, in as simple a manner as possible, the facts that are now known regarding mosquitoes and how to deal with these pests, and it is hoped that this information may help to secure a more general cooperation in the work of mosquito extermination.

Few people realize that there are a great many different kinds of mosquitoes. Some three hundred species have already been described, and here in the United States we have about fifty species, belonging to nine different genera. The most common of these genera in the northern states are *Anopheles*, the malarial, and *Culex*, the ordinary, mosquito. Of the former there are two species and of the latter at least fifteen.

Only these two genera and the methods for their extermination will be especially considered, and as these methods may also be successfully applied to the other kinds of mosquitoes, no detailed description of the others need be given.

* Illustrated with photographs from life by the author. The article and the photographs are copyrighted.

It is commonly and quite naturally thought that mosquitoes breed in wet grass, as they are often seen to rise from it in clouds when disturbed, particularly in the early morning and evening. They have not bred there, however, but have merely sought the shelter of the grass where they can be protected from the wind. The moisture of the dew upon the grass also furnishes an attraction for them and they always prefer damp rather than dry places.

Another popular theory is that mosquitoes will breed *only* in foul or stagnant water. This is also a mistaken idea though they often do breed in such water, not because it is impure or stagnant, however, but because these places are usually quiet and here the female can deposit her eggs undisturbed.

It is commonly supposed that mosquitoes do not breed in salt water, but the recent 'Mosquito Investigations' of Professor John B. Smith, of New Jersey, which were published in the New Jersey Agricultural College Experiment Station Report of November, 1902, show that the larvæ of *Culex sollicitans,* the 'Salt marsh mosquito,' not only prefer salt or brackish water, but are seldom found in pools where the water is strictly fresh, and, contrary to the usual custom, this mosquito lays its eggs upon the soil of marsh or meadow land. There the eggs remain until the advent of an unusually high tide. Then after a few hours when the water has covered them, the infant larvæ make their appearance.

It is very generally believed that mosquitoes bite but once and then die. This is sometimes so; but, unless they are killed in the act of biting, they usually live to bite again. The female mosquito (for it is only the female that attacks human beings) bites many times. It is owing to this fact that *Anopheles* is able to convey the germs of malarial fever from person to person. When biting any one who is afflicted with malaria, the insect draws in with the blood the germs of the disease, which it afterwards carries on into the blood of another victim. The vast majority of mosquitoes never get human blood for food. In its absence they live upon the blood of birds and other animals, and when these are not to be found, upon the juices of young and tender plants.

It is not known just how long mosquitoes can live, but their average life is much longer than is ordinarily supposed. Thousands of them live through winter hibernating or asleep in dark places in barns or house cellars. In sparsely settled localities, where they can not find such places for shelter, they live through the winter in hollow trees, in caves and holes under upturned trees; and, even though the temperature may fall far below freezing, they are not winter-killed, but on the approach of warm weather become active again. Mosqui-

toes are frequently seen flying about in the woods before the snow has wholly left the ground.

Mosquitoes can not develop or come to maturity without water in which to live during the first weeks of their 'wiggler' existence.

FIG. 1. MOSQUITO 'WIGGLERS'—LARVÆ AND PUPÆ—IN THE WATER. Life size.

A mosquito's life is divided into four stages—the egg, the larva, the pupa and the adult insect. In the larval and pupal stages, mosquitoes are more commonly known as 'wigglers' (see Fig. 1). Both

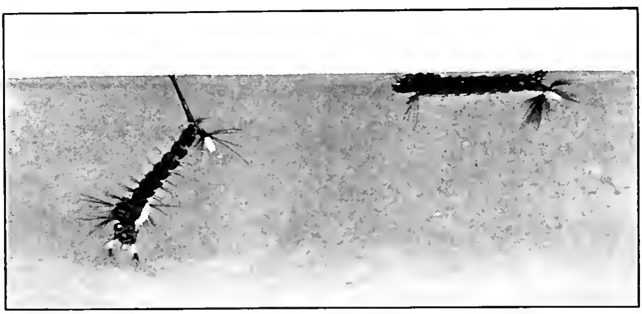


FIG. 2. MOSQUITO 'WIGGLERS' (LARVÆ) IN THE WATER. *Anopheles* LARVA TO THE RIGHT, *Culex* LARVA TO THE LEFT. Three times larger than life.

Anopheles, the malarial, and *Culex,* the common, mosquito larvæ are present in this picture. Mosquito 'wigglers' may frequently be found in rain-water barrels in as large numbers as are seen in this photograph. The female mosquito lays from one hundred and fifty to four

hundred eggs upon the surface of some quiet water, and in a day or two these eggs develop into the larval or second stage (see Fig. 2).

It will be noticed that *Culex* hangs with its head down, and from its tail upward to the surface of the water extends a small tube. Through this tube it breathes. *Anopheles* rests just beneath and parallel to the surface of the water, and its breathing tube is much shorter than that of *Culex*. These resting positions are quite different, and each is characteristic of its kind. Except when disturbed, *Anopheles* is generally to be found at the surface, breathing and feeding in this position. *Culex,* on the other hand, comes to the surface only occasionally to breathe. It stays below the water for the greater part of the time, and is often found feeding from the bottom.

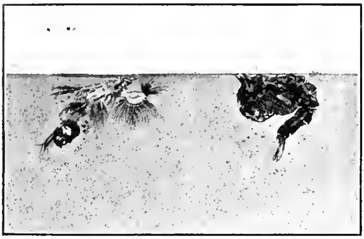


FIG. 3. A PUPA, THE THIRD STAGE IN A MOSQUITO'S LIFE. Three times as large as life.

At the end of a few days the larvæ change into the pupal or third stage (see Fig. 3). To the left is seen the larval skin out of which this pupa has just come. The difference between *Culex* and *Anopheles* in this, the final stage of 'wiggler' existence, is very slight. Both now

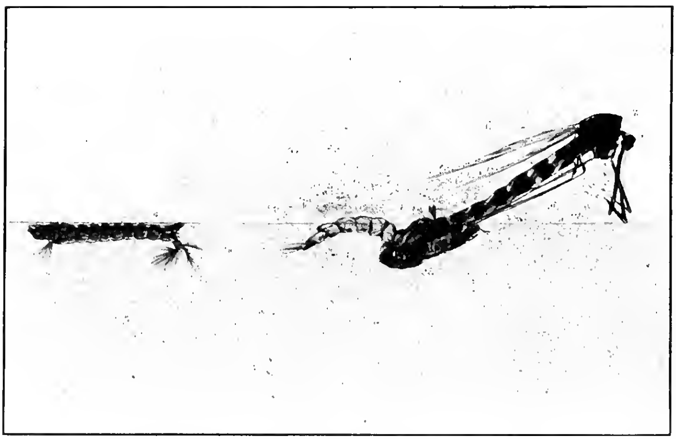


FIG. 4. AN ADULT MOSQUITO (*Anopheles*) TRANSFORMING FROM A PUPA AND COMING OUT OF THE WATER. Three times as large as life.

live at the surface of the water, and they breathe through two funnel-shaped tubes situated one on each side of the thorax, or 'head.' Unless disturbed, they remain motionless in this position at the surface until the time comes when, as adult mosquitoes, they leave the water (see Fig. 4). This is the critical period of a mosquito's life; for, should

the surface of the water be disturbed at this time, the insect would be upset and drowned. It takes about seven minutes from the time when the skin along the back of the pupa begins to split until the full-grown mosquito comes forth and in a few minutes is ready to fly away. A mosquito never grows any larger after this change.

The length of time required to pass from the egg to the adult insect varies from ten days to three weeks, according to the temperature. Warm weather hastens their development, while low temperature checks it. The 'wigglers' of some species of mosquitoes live through the coldest weather of our northern winters unharmed, ready, when the first warm days of spring have come, to complete their natural changes.

Mosquitoes' eggs are so very small that ordinarily they remain unnoticed, but nearly every one who lives in the country is familiar with the little 'wigglers' that are often seen squirming up and down in rain-water barrels. Few people know that these little fellows are connected in any way with mosquitoes, but it is a very easy matter to prove that they are. Let any one who doubts this fact dip up a few in a glass jar or tumbler and place them in the house, where they can be frequently looked at. Seeing is believing; and after a full-grown mosquito has once been seen to come forth from a pupa (which is the last stage of the 'wiggler'), there can not any longer be any question as to what these 'wigglers' really are.

Most of the mosquitoes that annoy us are bred near by, often, though unknown to us, in our own dooryards. Any water that is accessible to mosquitoes and whose surface is undisturbed by winds or rapid currents furnishes a breeding-place for them, and 'wigglers' may often be found in water standing in old tin cans or bottles, in rain-water barrels, in pools in the rocks, in roof or street gutters that are not properly drained, in cesspools or in catch-basins, in fact, in any place that will hold water for a week or two, no matter how small the quantity, even if only a few teaspoonfuls.

Since we know that without water mosquitoes in their first stages can not exist, it naturally follows that all standing water should be done away with or treated in such a manner that 'wigglers' can not live in it nor mosquitoes get to it to lay their eggs. To this end all cans, bottles and every discarded utensil that will hold water should be removed. All stagnant pools, where it is possible to do so, should be drained or filled up. Cisterns, rain-water barrels and cesspools should be screened or otherwise covered to prevent the adult insects from having access to them. Where it is not practicable to fill, drain, or screen the places that are suitable for mosquitoes to breed in, the surface of the water may be covered with kerosene oil. This oil, when spread over the water, prevents the 'wigglers' from getting air

when they come to the surface to breathe, and so kills them (see Figs. 5 and 6).

In Fig. 5 a 'wiggler' is seen trying to get air, vainly thrusting its breathing tube up into the film of kerosene.

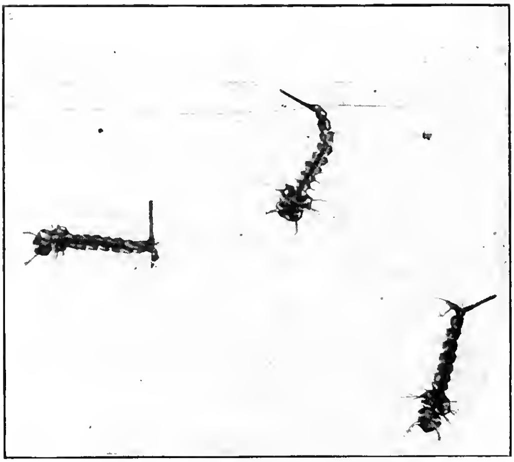


FIG. 5. THREE TIMES LARGER THAN LIFE.

In Fig. 6 the upper 'wiggler' is grasping its breathing tube in its mouth, apparently trying to pull off the small particles of kerosene

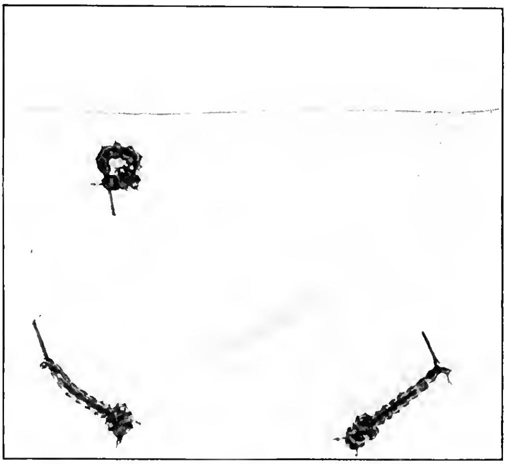


FIG. 6. THREE TIMES LARGER THAN LIFE.

with which the tube has been clogged. The 'wigglers' upon the bottom have been suffocated and have given up the fight.

An ounce (two tablespoonfuls) of kerosene will spread over fifteen square feet of water surface, forming a film thick enough to kill all

the 'wigglers' that are beneath it. Kerosene of a cheap quality, known as high test light fuel oil, is preferable for this purpose. It can usually be bought at eight cents a gallon. If oil of this quality is not available, ordinary kerosene will answer the purpose. It should be applied as often as once in two weeks, for by that time the previous applica-

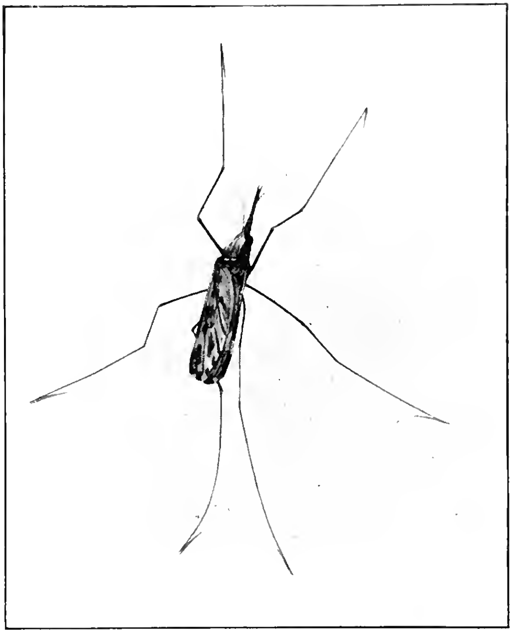


FIG. 7. *Anopheles punctipennis* (FEMALE). Three times larger than life.

tion will have evaporated. A sufficient quantity should be used, in the proportions named, to cover completely any place that may need treatment.

Any one who is ill with malaria or yellow fever should be carefully protected from mosquitoes, for, should a person be bitten by an *Anopheles*, the malarial mosquito or *Stegomyia fasciata*, the yellow fever mosquito, at this time, there would be great danger that the insects might fly away and bite some one else and thus spread these diseases. Screens for both doors and windows form the best protection against mosquitoes at all times; but it often happens that the insects get into our houses, even though they are thoroughly screened, generally through some door or window that has been left open by mistake, or they may gain an entrance by coming down an unused chimney if the flue is allowed to remain open during the summer time. A house or a room may be cleared of mosquitoes by burning pyrethrum powder and allowing the smoke, which is not at all offensive to most people, thoroughly

to fill the room that is under treatment. This smoke kills or so stupefies the insects that they will not bite. Pyrethrum powder is a preparation of the plant *Pyrethrum roseum,* and is sometimes sold as Persian Insect Powder or Dalmation Powder; it can be bought at any drug store for about thirty-five cents a pound. It is a very fine, light powder; and an ounce of it will go a long way, making a large volume of smoke. A pyrethrum smudge or smoke may be started by covering a live coal, taken from the kitchen stove, with the powder, first placing the coal upon a small shovel, so that it may be moved about conveniently without danger of setting anything on fire. The pyrethrum will

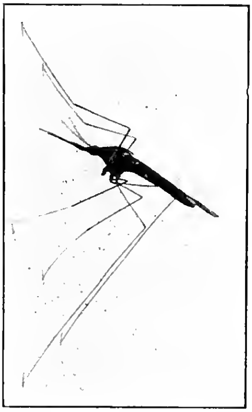


FIG. 8. PROFILE OF *Anopheles punctipennis* (FEMALE). Three times larger than life. Showing the characteristic resting position of this mosquito.

FIG. 9. PROFILE OF A *Culex* MOSQUITO (FEMALE). Three times larger than life.

quickly begin to smoulder and give off a dense smoke. All that is now necessary is to add from time to time a pinch of the powder as occasion requires, merely keeping the smouldering ashes covered so that they will give off a smoke. People are frequently annoyed and sometimes driven into their houses on summer evenings by the persistent attacks of mosquitoes. On such occasions, pyrethrum powder can often be used to advantage; and the smoke from a small quantity of the powder kept smouldering upon the piazza will drive away most, if not all, of the pests, thus making it possible to enjoy an evening out doors in comfort, when otherwise life would be unbearable except behind the protection of screens.

The *Anopheles,* or malarial mosquitoes, though not very common (see Figs. 7 and 8), are breeding quite abundantly in many parts of this country; and by referring to the accompanying photographs, particularly the ones in profile, it will be seen that there is quite a difference between the malarial and the common, or *Culex,* mosquitoes.

They may easily be distinguished from the common or *Culex* family of mosquitoes by the spots upon their wings, and also by the position which they take when at rest (see Fig. 8).

Notice the angle at which the insect shown in Fig. 8 stands out from the wall. Compare this with Fig. 9. It will also be seen that the proboscis, or 'stinger,' and the body of *Anopheles* form a straight line, while the *Culex* is rather humpbacked. The other *Anopheles, maculipennis,* does not stand out from the wall at quite such an angle as does *punctipennis;* but like the latter its proboscis and body form a straight line, and the angle formed by the insect when at rest is much greater than that of the *Culex.*

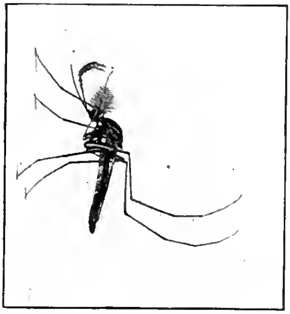


FIG. 10. PROFILE OF A MALE *Culex* MOSQUITO. Three times larger than life.

Notice how different is the resting position of the mosquito in Fig. 9 from that of *Anopheles* in Fig. 8.

The male mosquito (see Fig. 10) never bites. He may be easily distinguished by his large and feathered antennæ and palpi, which are very much more prominent than those of the female.

There is another mosquito, *Stegomyia fasciata,* which in form and habits closely resembles *Culex,* in which genus, until quite recently, it was classed. *Stegomyia fasciata* is the yellow fever mosquito, and it only inhabits the warmer portions of this country. It is common in most of our southern states and is seldom seen north of the Carolinas. It is easily distinguished from other mosquitoes by the conspicuous silvery white stripes upon its thorax and abdomen, and by the white bands upon its legs.

Fortunately for mankind, nature herself provides many energetic workers who are constantly doing their part towards holding in check these insect pests. Foremost among these natural enemies are many of the insectivorous birds, which daily destroy many thousands of mosquitoes. The swallows, the fly-catchers, the night hawks and the whip-poor-wills, all are insect exterminators, whose good work in this connection is seldom taken into account. The bat is also an efficient mosquito hunter; so too are the dragon flies which frequent the shores of ponds and pools where mosquitoes breed.

Besides these enemies of the adult mosquito, which may properly be called their 'foes of the air,' mosquitoes have other adversaries which destroy them in their early stages. These may be termed their 'foes of the water.'

It often happens that we can find no 'wigglers' in small ponds in which we would naturally expect to find mosquitoes breeding. In

such ponds the presence of fish may account for the absence of mosquitoes. Their larvæ furnish food for many species of our smaller fishes, and by them myriads of mosquitoes are annually destroyed. Goldfish are particularly fond of mosquito 'wigglers,' and the pair of fish in the illustration (see Fig. 11) were seen to eat ninety-eight 'wigglers' in four minutes. Goldfish will live and multiply in almost any small and shallow pond in this vicinity, where the water is warm. They are perfectly hardy and will thrive just as well and perhaps better in stagnant water than they will in fresh.

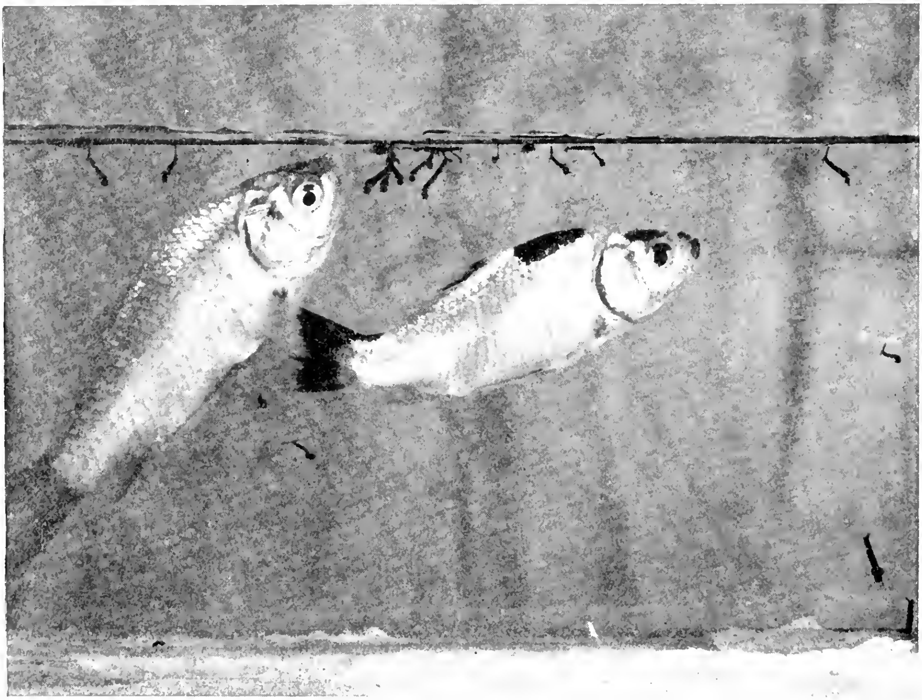


Fig. 11. Goldfish Eating Mosquito Larvæ. Life size These two fish were seen to eat ninety-eight 'wigglers' in four minutes. They always fed upon mosquito larvæ when they could get them in preference to prepared goldfish food.

The 'top minnow,' the wach, the sunfish or 'pumpkin seed' and even the sluggish horn pout all play an important part in reducing the numbers of mosquito 'wigglers.' Besides the fishes, there are other 'foes of the water' that prey upon mosquito larvæ. Many of the predatory water bugs feed upon them. Professor J. B. Smith, in the report previously referred to, says that "among these predatory insects which abound in shallow permanent bodies of water wherever there is vegetation, the water boatman (*Corisa* and *Notonecta*), the water striders or 'skate bugs' (Hydrobatidæ) and the water scorpions (Ne-

pidæ, Belostomatidæ) deserve mention.'' He also speaks of the 'water tiger,' the larva of the large water beetle (*Dytiscus*), and tells of its ability to clear *Culex* larvæ from pools of water.

In this connection a brief description of a newly discovered mosquito,* to which has been given the name *Eucorethra underwoodi*, should be of interest, since it has been found that their larvæ devour the wigglers of other mosquitoes, and unlike other mosquitoes, the adult female insect does not bite. As the proboscis of this insect is so formed that it can not puncture the skin, it should not perhaps be called a true mosquito, though it has been classed as one, since it belongs to the family Culicidæ.

The larvæ of this insect were found by the author on January 27, 1903, in the Maine woods in the eastern section of Penobscot County, and were discovered in a spring of water from which a crew of lumber-

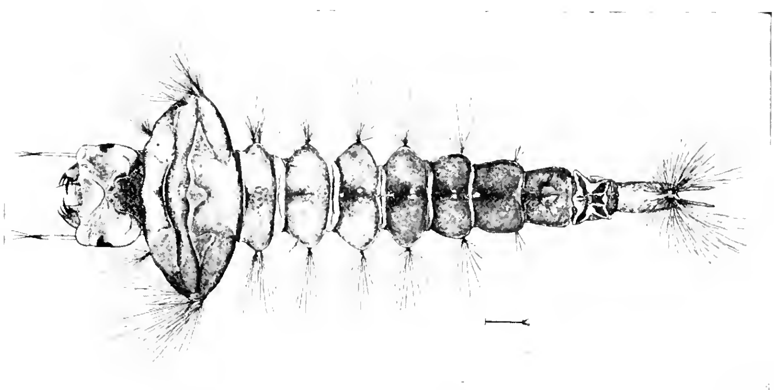


FIG. 12. LARVA *Eucorethra underwoodi*. DORSAL VIEW.

men were getting their water supply. A few days later, other larvæ of the same species were found in a similar spring about eight miles distant, though in this case, as the spring was not in use, its surface was covered with a coating of ice an inch thick. The temperature of the water at the bottom (it was about two feet deep) was 42° F.

At first sight this larva would be taken for an *Anopheles* of extraordinary size, as it is of the same general shape, and when the water was cleared of ice, it lay just beneath and parallel to the surface, breathing through a short respiratory siphon, as is characteristic of the larvæ of *Anopheles*. In this spring a barrel had been sunk and in the fifty gallons, or thereabouts, of water which it contained there were twenty-five larvæ. They were all of about the same size—12 to 14 mm. long

* Under the title 'A New Mosquito' a description of this mosquito appeared in *Science*, August 7, New Series, Vol. XVIII., No. 449.

—and almost black in color. All were secured and taken into camp for further investigation.

Close observation of the larvæ showed that besides being much larger (12–14 mm. long instead of 5–7 mm.) they differed in many other particulars from the larvæ of *Anopheles* (see Fig. 12). In proportion to the rest of its body, its head is larger than the head of *Anopheles*. It does not turn its head upside down when feeding as does *Anopheles*. Its mandibles are strikingly large and powerful and are prominently toothed. It lacks the frontal tufts or brushes which are conspicuously present in *Anopheles*, and its antennæ, which extend directly forward parallel with the sides of the head, are much longer and more slender, and are tipped each with three hairs of equal size. The thorax is broadly elliptical and is much wider in comparison with its abdominal segments than is the thorax of *Anopheles*. The sides of the thorax and the abdominal segments bear fanshaped tufts of hairs, not plumosed as in *Anopheles*. The tufts on the last segments, both dorsal and ventral (see Fig. 13), are more profuse in *Eucorethra* than in *Anopheles*, especially the ventral tuft which in *Eucorethra* occupies nearly the whole segment. Only two anal papillæ are present, while *Anopheles* has four.

FIG. 13 LAST SEGMENT OF LARVA PROFILE.

A few days before the author returned to Boston, several larvæ died and three changed to pupæ. The pupa resembles that of *Culex* (see Fig. 14) rather than of *Anopheles* and its respiratory siphons are of the same shape as those of *Culex*. When stretched out at full length, the pupa measures ten mm.

On reaching home, the new wigglers, eighteen in number, were put into a quart jar which was placed near a window where it would receive the sunlight for two hours each morning. The temperature of the water now averaged about 70° F., and with this change the larvæ developed a new trait—they began to eat each other up. The act was witnessed on several occasions. The larva would grasp its adver-

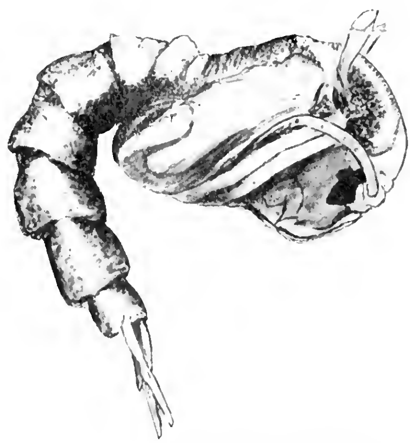


FIG. 14. PUPA *Eucorethra underwoodi*. ORIGINAL DRAWING.

sary just forward of the respiratory siphon with its powerful mouth parts, and working the tail in first it would gradually swallow its victim, shaking it now and then as a terrier would shake a rat.

After losing many of the insects in this way, those that remained were separated, and each individual was placed in a small bottle by itself. Eventually, I succeeded in rearing a number of

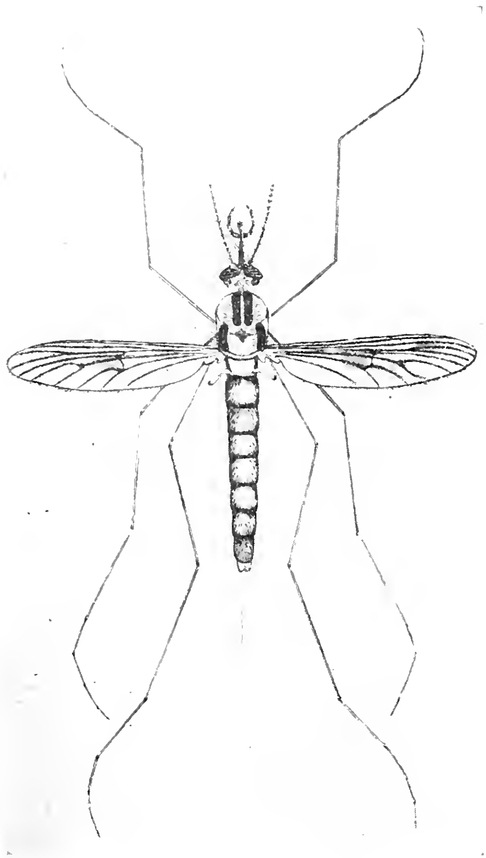


FIG. 15. *Eucorethra underwoodi.* COQUILLETT MS. ORIGINAL DRAWING.

males and females. The pupal stage of this insect varies from five days and nine hours to six days and ten hours. The adult (see Fig. 15) resembles *Anopheles* in having maculated or spotted wings, but is much larger and measures eleven millimeters in length. Its mouth parts, however, are not adapted for biting. A full description of the imago is soon to be recorded by Mr. D. W. Coquillett, of the National Museum, by whom the name above mentioned was given.

During a visit to Maine in June, a large number of larvæ of *Eucorethra* were taken from the spring where the barrel had been sunk. It was noticeable that larvæ of other kinds of mosquitoes were absent, although the adults were very numerous in the immediate vicinity.

The absence of other mosquito larvæ was accounted for when later it was discovered that the larvæ of *Eucorethra* fed upon the larvæ of other mosquitoes, eating them apparently with great relish. On several occasions fourteen *Eucorethra* larvæ ate, during the night, sixty *Culex* larvæ out of the seventy that had been placed in the water with them. When eating the larvæ of mosquitoes smaller than themselves, the victim is caught, shaken violently a few times, and swallowed in a few seconds in very much the same way that a pickerel would catch and swallow a smaller fish.

As yet no experiments have been made to see if this new species will devour the larvæ of *Anopheles* as readily as they will those of *Culex*. Whether or not this species will thrive in the climate of southern New England is as yet uncertain, but experiments are now being carried on to determine this point.

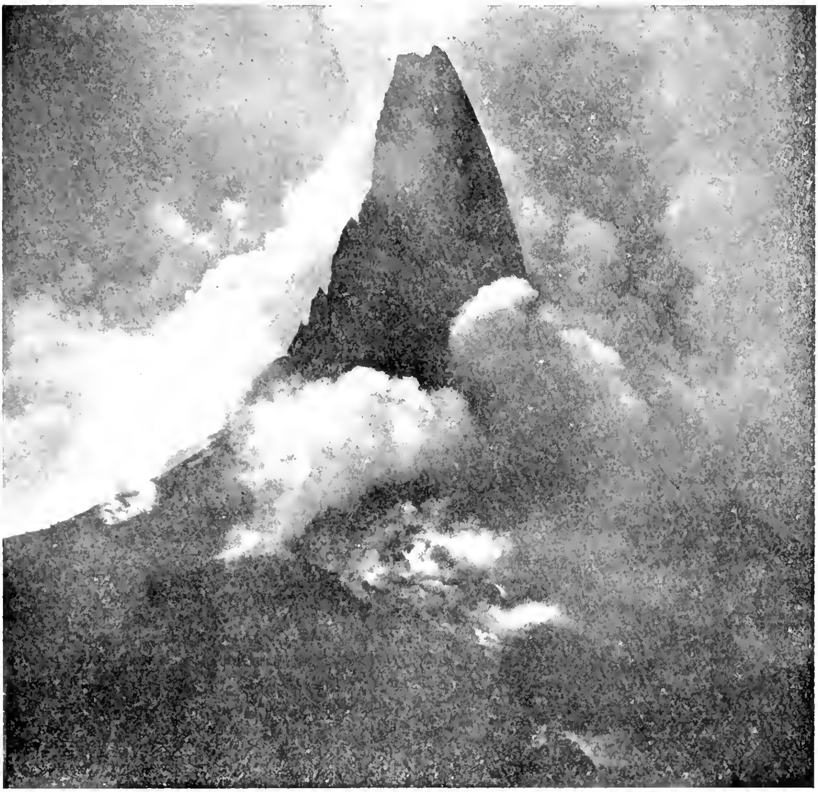
Although myriads of mosquitoes are destroyed by the natural enemies which have been mentioned, *man should* be the most destructive foe of these insects. There is no doubt that the mosquito pest may be very largely abated by the employment of scientific methods for causing its destruction in the early stages of its development.

While it is the duty of boards of health to recognize mosquitoes as active agencies for the dissemination of certain diseases and to take such measures as are possible for their extermination, the work can never be effectively done until the people of each community are fully informed in regard to the life history of the mosquito so that all may cooperate intelligently to secure its destruction.

SHORTER ARTICLES AND CORRESPONDENCE.

THE ASCENDING OBELISK OF THE MONTAGNE PELÉE.

The extraordinary shaft of rock (lava) shown in the illustration now transfixes the newly-constructed cone of Pelée, and towers above it upward of 800 feet, giving to the volcano a height of 5,020 feet, instead of 4,250 (or 4,400) feet, which it had prior to the eruption of May 8, 1902. This unique structure which, on May 31 of this year, rose still 180 feet higher, is being and has been pushed up bodily, the lava solidifying before leaving the interior of the volcano. During the four days immediately preceding June 17, as determined by M. Guinoiseau, a member of the French Scientific Commission in Martinique, the lift or ascent was nearly 21 feet, but at an earlier day the movement was much more rapid. The obelisk, which meas-



Obelisk of Pelée. (Photograph by Angelo Heilprin, from the crater-rim of Pelée, June 13, 1903 (elevation, 4,100 feet).

ures 300–350 feet across at the base is slightly curved in the direction of Saint Pierre; the eastern face is smooth and grooved, showing well the marks of attrition against the encasing wall of rock which lined its channel of exit. On the west and southwest it is 'cavernous' and slaggy, having the impress of successive eruptions which have blown its parts asunder. On the night of June 12, immediately preceding my ascent, the southwest base was intensely luminous, shining out bright red with the lava that was being forced into it. A few days later, a thin vapor pennant was seen to issue from the absolute apex. Basal eruptions were taking place almost continuously.

ANGELO HEILPRIN.

PROFESSOR SHALER ON ANIMAL INTELLIGENCE.

TO THE EDITOR: Permit me to call your attention to an article by Professor N. S. Shaler in the July issue of *Harper's Monthly* under the caption 'Plant and Animal Intelligence.' This article contains so many glaring inaccuracies and misinterpretations of the views of Huxley, the monistic philosophers and those whom he terms 'men of the extreme Darwinian school' that in the interest of scientific truth—of which your journal has always been such a valuable exponent—some action on your part to correct the evil effect of these errors would be both timely and consistent. Now, I am not posing as a champion of monistic philosophy, but the public should not be misled with respect to what monism really means, nor should the broad-minded Huxley, the enemy of dogma, whether in science or religion, be held responsible for views not only foreign to his beliefs, but incompatible with his habits of thought.

Professor Shaler asserts that Huxley was the originator of the theory of animal automatism. One is tempted to believe that the learned professor has had no time to peruse Huxley's monograph on the subject, but has jumped at the conclusion that the title signifies a belief in that theory in its narrowest sense. The great name of Descartes, the real originator of the theory, is not even mentioned, and Professor Shaler seems to be ignorant of the fact that Huxley's interesting monograph is merely a critical analysis of Descartes's thesis, leading to the inevitable conclusion that the great seventeenth century philosopher's views on the subject were untenable, although in part justified by his marvelously prophetic insight into the truths of modern psychology and physiology.

The following extracts from Huxley's monograph show very clearly his thought on these subjects:

> But though I do not think that Descartes' hypothesis can be positively refuted, I am not disposed to accept it. The doctrine of continuity is too well established for it to be permissible to me to suppose that any complex natural phenomenon comes into existence suddenly, and without being preceded by simpler modifications; and very strong arguments would be needed to prove that such complex phenomena as those of consciousness, first make their appearance in man. . . . We know, further, that the lower animals possess, though less developed, that part of the brain which we have every reason to believe to be the organ of consciousness in man; and as, in other cases, function and organ are proportional, so we have a right to conclude it is with the brain; and that the brutes, though they may not possess our intensity of consciousness, and though, from the absence of language, they can have no trains of thoughts, but only trains of feelings, yet have a consciousness which, more or less distinctly, foreshadows our own.

It is true that Huxley, in another part of his essay, offers the postulate that man, and other higher organisms, are *conscious automata*, but this is very different from believing, as Professor Shaler asserts he did, 'that mind was a peculiarity of man, the lower animals being essentially automata, all their apparent intelligence being due to mere reflex action essentially comparable with mechanical movements such

as those of sensitive instruments—with no intelligence whatever in the action.'

Now, while the word automaton, in the literal sense, may be offensive as applied to man, coupled with the word 'conscious' it merely signifies a negation of the doctrine of free will or uncaused action. In other words, Huxley suggests that the state of consciousness preceding any so-called voluntary act is merely a part of the mechanism of that act, and not its cause, the cause being found in immediate external stimuli and molecular conditions, the result of the accumulated effects of more remote external stimuli incident during both individual and ancestral existence, and forming links in a long chain of causation which is finally lost in the infinite and absolute cause of all things.

Professor Shaler laboriously seeks to prove by Huxley's own familiar arguments the analogy between the psychic life of animals and that of man. It is really amusing to find Huxley, the author of 'Man's Place in Nature' and always a believer in the continuity of organic life, credited with doctrines actually subversive of his most cherished theories.

The philosophers of the extreme 'Darwinian' and monistic schools would be astonished and shocked, I am sure, to learn that they have committed philosophical 'hari kari' by regarding an elephant as an automaton. Surely the formation of species by the almost inconceivably slow and gradual process described by Darwin is incompatible with any theory calling for the sudden appearance of conscious man. Such a theory might be held more consistently by De Vries or others who question the validity of Darwin's generalizations and ask us to believe in the sudden 'mutation' of species.

One is loath to believe Professor Shaler serious in his statement that the monists have sought to establish their conception of the universe by exploiting a distinctly dualistic theory. Ernst Haeckel, who may be cited as a type of the extreme monistic school, asserts his belief that consciousness in the true sense of the word is present in all organisms having a centralized nervous system; furthermore, Haeckel invites us to the study of the 'sublime monism of Spinoza,' which, after all, is the very pantheism which Professor Shaler says has never held an important place in occidental philosophy.

It is not a far cry from Spinoza's self-existent universal substance, of which consciousness is only a mode, or Schelling's 'world soul' composed of the *union* of a positive and negative principle to Spencer's 'unknowable absolute.' In Spinoza and Schelling we have the pantheism of the East purified and shorn of its allegory and imagery. In Spencer we have the essentially modern, scientific arrangement of the data of our consciousness leading to conclusions only faintly adumbrated in the hazy speculations of *a priori* philosophers.

It has become the fashion lately in certain quarters to disparage the work of that splendid band of truth seekers who created modern science, not only by what they contributed in exact knowledge, but by the inspiration they afforded others and the impetus they gave to rational methods of research and speculation. Doubtless the generalizations of the great evolutionists will be modified by advancing knowledge, but I am confident that far into the future the pathway blazed by these men through the wilderness of ignorance, tradition and error will always be found leading towards truth, though possibly at times through tortuous ways. Hero worship and the weight of authority should not be permitted to stay the march of progress, but the cause of science is not best served by reading into the works of the great men of the past views which they would have been the first to repudiate.

EUG. L. FISK.

NEW YORK.

SCIENTIFIC LITERATURE.

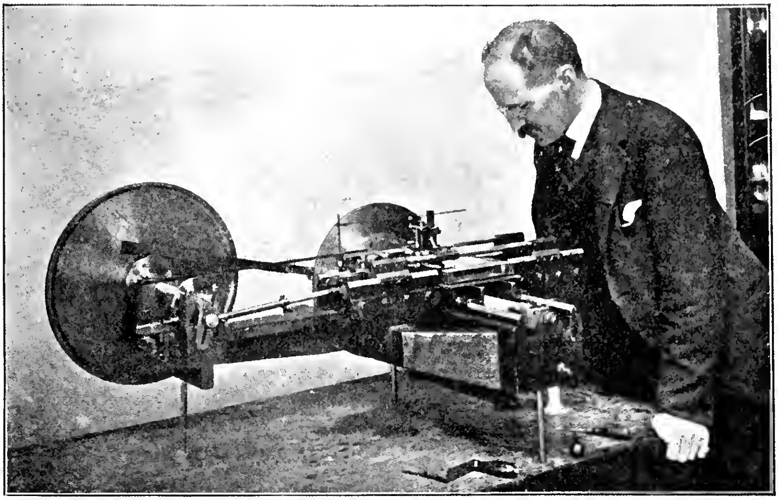
THE COLLECTED PAPERS OF ROWLAND AND FITZGERALD.

We had occasion to note recently the severe losses of mathematical physics and Gibbs in the United States were given time for a full life's work, but Rowland and FitzGerald were prematurely cut down, each at the age of

Henry A. Rowland.

in the deaths of those to whom this most fundamental of the sciences is deeply indebted. Stokes in England about fifty years. The Johns Hopkins University has recently published the 'Physical Papers' of Rowland, edited

by a committee of which Professor Ames was the responsible member, and the Dublin University Press has published the 'Scientific Writings' of FitzGerald, edited by Dr. Joseph Larmor. These memorial volumes should be in the hands of many who are not physicists by profession. It is true that some of the papers contain mathematical formulas and technical statements not comprehensible to those without special training. But each volume also includes a number of masterly addresses revealing the progress of physical science, and the researches give an excellent introduction to the fundamental concepts of modern physics. They show science in the making in a way that is in many respects more attractive than a systematic treatise.

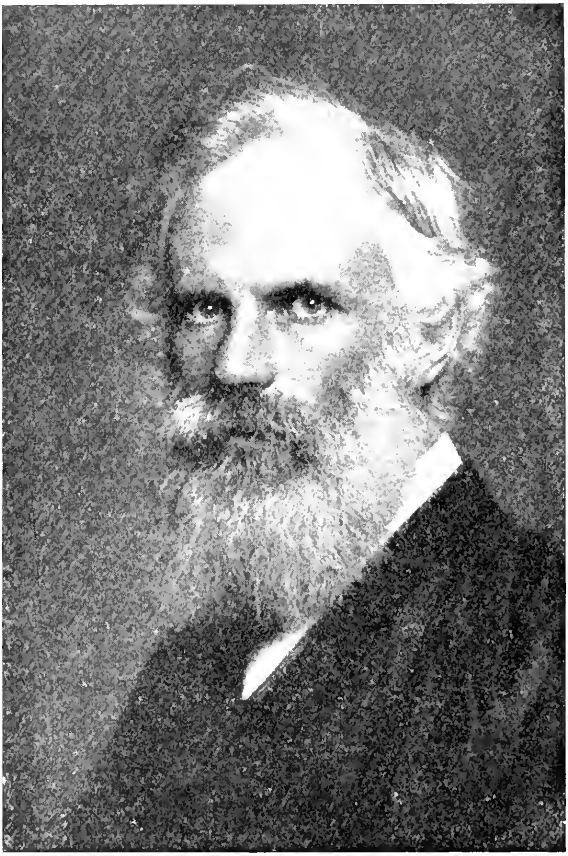


PROFESSOR ROWLAND'S DIVIDING ENGINE.

Rowland was by common consent the leading experimental physicist of his generation in this country. In one of his addresses he could only mention four American physicists of note—Franklin, Rumford, Henry and Mayer. Fundamental as the work of Franklin and Rumford proved to be in the history of science, it was in a way amateur in character, incidental to more absorbing activities; and Rumford's work can scarcely be credited to America. Henry's investigations were also fundamental, but they were in large measure fragmentary and unpublished. Mayer's ingenious experiments can scarcely be regarded as of great importance. Rowland may thus be regarded as the greatest experimental physicist that America has produced. He himself attributed our lack of productivity in pure physics to the counter attraction of invention and money-making; and in one of his addresses spoke very bitterly of the university professor who prostituted his chair to such uses. It is, however, not clear why a group of able inventors and experts should not lead to pure science as well as away from it. Rowland himself patented important inventions, as his application of alternating currents to rapid telegraphy, and acted as expert for engineering enterprises, as the electrical development at Niagara Falls.

Rowland's researches fall into three main groups—magnetism and electricity, heat and light—and in each

he made contributions of great importance. His early work on magnetic permeability attracted the attention of Maxwell, and his subsequent research on the magnetic effect of moving electrostatic charges was fully appreciated by Helmholtz, in whose laboratory it was carried out. Sixty-three papers on magnetism and electricity are included in the memorial volume. The research on the mechanical equivalent of heat was somewhat routine in character, determining with the most painstaking accuracy one of the most important physical constants. The photographic map of the normal solar spectrum and the determination of absolute wave-lengths were also the results of long-continued and careful detailed work, but they were made possible by the important work on screws, the construction of the famous dividing engine, and the great discovery of the use of a concave grating.



Geo. F. FitzGerald.

Rowland was fortunate in being called to the Johns Hopkins University at its organization, where for the first time in America the value of original research was fully appreciated and opportunity for research freely granted, and the university was fortunate and wise in calling a man who added so greatly to its reputation and influence. It is told of Rowland that when, in a

suit over the value of his services, he was asked who was the greatest living physicist, he replied that he was. On being asked afterwards if this did not seem rather egotistical, he answered: 'I had to tell the truth, I was testifying under oath.' His personality was attractive to those who knew him well and understood his supreme absorption in his own work. To others he doubtless seemed self-centered, somewhat unsympathetic and undemonstrative. FitzGerald appears to have had exactly the opposite characteristics. Physiognomy is extremely illusive, but the portraits here given seem to indicate the individualities of the two men. FitzGerald was unselfish and self-sacrificing almost to a fault. Dr. Mendenhall tells us in his commemorative address that Rowland did not know even approximately how many students he had, and on being asked what he would do with them, replied: 'Do with them?—I shall neglect them.' But he adds: 'To be neglected by Rowland was often, indeed, more stimulating and inspiring than the closest personal supervision of men lacking his genius and magnetic fervor.' FitzGerald sacrificed his research work to teaching, to administration and to helping others; he was always ready to give his ideas to students and to his friends. He took no interest in questions of priority and scientific credit. Rowland spoke of 'professors degrading their chairs by the pursuit of applied science.' FitzGerald said that it was a small matter whether the human race got to know about the ether now or fifty years hence, but that it was a vital matter that present scientific ignorance should not continue for a generation.

FitzGerald tended to devote himself more and more to human affairs, giving much time to the Irish Education Board and visiting this country to observe our schools; but the memorial volume containing his collected papers shows that he did contribute greatly to our knowledge of the ether. He was almost the first to appreciate fully Maxwell's work and to carry it forward, his memoir 'On the Electromagnetism of the Reflection and Refraction of Light,' presented before the Royal Society in 1888, being accepted as a classic. Many of his other papers contain important contributions and suggestions, and the addresses should be of interest to all those who are able to appreciate the great forward advance in our views on the nature of electricity and the constitution of matter. It may be noted as of incidental interest that FitzGerald did not go to school as a boy; his father was an eminent bishop, and his mother a sister of the mathematical physicist, Professor Johnstone Stoney.

JOHN ERICSSON.

THE PROGRESS OF SCIENCE.

JOHN ERICSSON.

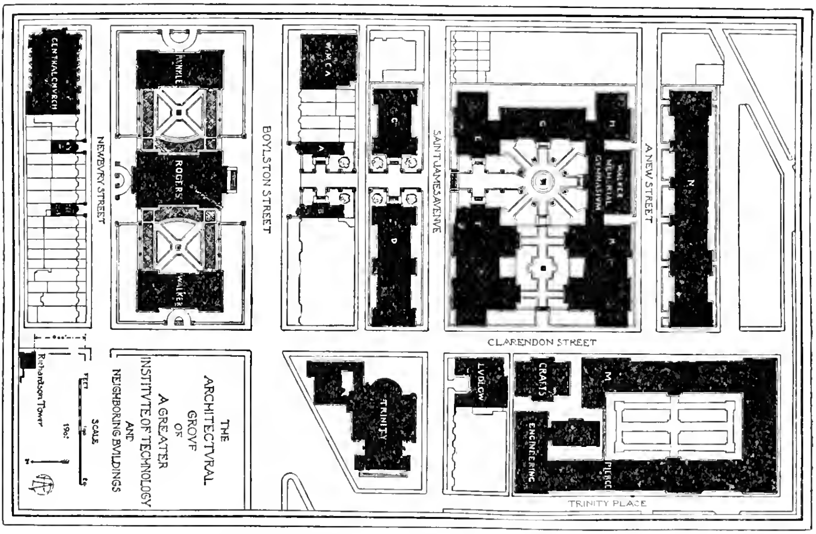
The centenary of the birth of John Ericsson was celebrated on August 1 by the unveiling of a statue in the Battery, New York City. A bronze statue by Mr. Jonathan S. Hartley had for ten years stood near the Custom House, but the sculptor wished to improve it, and at his own expense made a new statue, in which the same metal was used. By the courtesy of Mr. Hartley, we reproduce a photograph of the model as it stood in his studio. The ceremonies connected with the unveiling of the statue were elaborate, the army and navy being represented, and the Swedish-American Societies taking a prominent part. Mayor Low accepted the statue for the city and Colonel W. C. Church, author of the life of Ericsson, made an address. Both speakers naturally referred to the building of the *Monitor* and its destruction of the confederate ironclad *Merrimac* on March 9, 1862. It will be remembered that on the preceding day the *Merrimac* had destroyed the *Cumberland* and the *Congress*, and was about to disperse the rest of the government's wooden fleet, when the *Monitor*, which had been built by Ericsson in New York in one hundred days, altered the course of events and perhaps the whole result of the civil war, for if the federal government had had no fleet, European intervention would have been likely. Shortly after Ericsson came to the United States in 1839, he built the *Princeton* for the United States Navy, the first vessel having the propelling machinery below the water line, and this vessel set the model for all subsequent naval construction. Ericsson is consequently remembered largely in connection with the development of ships of war, to which he made the most important contributions. His other great scientific inventions, however, should not be forgotten, especially the screw propeller, which while originally designed for warships has become one of the greatest factors in steam navigation. Europe was long sceptical as to the possibility of the propeller, it being claimed that a vessel would not steer when power was applied at the stern, even after many vessels were being successfully navigated in the United States.

Ericsson began his inventions when a boy in Sweden, and at the age of twenty-two constructed a condensing flame engine of ten horse power. In 1828, when twenty-five years of age, he made the first application to navigation of the principle of condensing steam and returning water to the boiler. In 1829, when twenty-six years old, he built the steam carriage, *Novelty*, which competed with George Stevenson's for the Liverpool and Manchester railway prize. It surpassed all competitors, including Stevenson's *Rocket*, in lightness and speed, attaining the remarkable speed of thirty miles an hour. At this period and a little later he made numerous important inventions, including the tubular steam boiler with artificial draught and the caloric heat engine. He also made some important instruments for scientific work, including the self-registering deep-sea lead, a pyrometer and a hydrostatic gauge. Ericsson must be regarded as one of these who made the nineteenth century before all else an era of the applications of science.

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

A movement is now in progress to establish a great school of technology in connection with the University of London. Through the efforts of Lord Rosebury, chancellor of the university, a sum of $2,500,000 has been subscribed for buildings and land. The London County Council has agreed to contribute $100,000 a year for maintenance on condition that the government and other municipalities take part in the movement. In all the discussions in regard to the establishment of this school of technology, reference has been made to the fact that Germany and America are in advance of Great Britain in their provision for technical education, and of all our schools, the Massachusetts Institute of Technology is the most noteworthy.

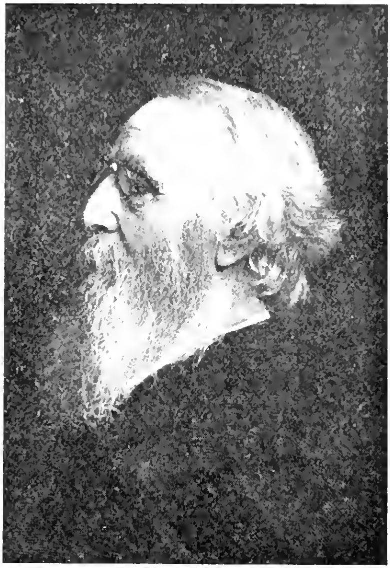
The institute is at present seriously considering the desirability of obtaining a new site. The land on which its buildings now stand having become part of the business quarter of the city, land adequate for the needs of the institute could only be purchased at great expense. The institute has recently obtained powers from the legislature to sell its present site should it wish to do so, it having originally been a condition that it forever be preserved from sale. This permission was not obtained without a considerable amount of opposition, and the parallel bill on behalf of the Society of Natural History has not been passed. There still appears, however, to be some opposition to the change. Mr. Henry A. Phillips contributed to the last number of *The Technology Review* a plan for developing the institute on its present site, as shown in the accompanying figure. The buildings now occupied by the institute are the Rogers, the Walker, the Engineering and the Pierce buildings. It is estimated that the land required for the development here sketched would be $1,800,000, according to the assessed valuation, whereas the removal of the institute would require the sacrifice of buildings worth perhaps $1,000,000.



Proposed Plan for the Enlargement of the Massachusetts Institute of Technology.

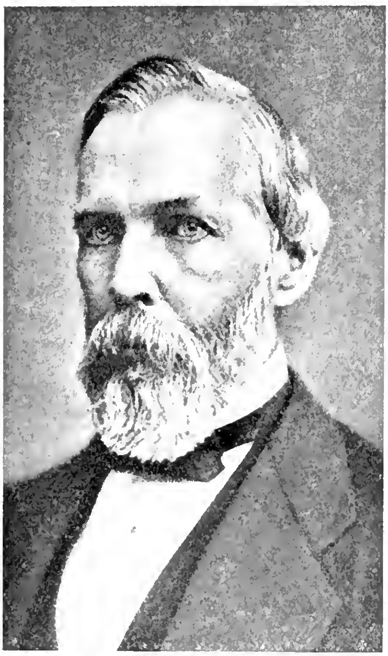
The Institute of Technology has this year made on its educational side an important advance in establishing a

graduate school of engineering research including two research laboratories, one for physical chemistry under the charge of Professor A. A. Noyes and one for sanitary engineering under the charge of Professor Wm. T. Sedgwick. The former is to occupy one of the new buildings now being erected beyond the Pierce building, and will consist mainly of a series of small laboratories, with special rooms for weighing, photography, glass-blowing, pure water distillation, etc. There will be next year nine or ten research assistants and associates working under the direction of the professors of the institute, and every facility will be given to advanced students wishing to carry on research work. The Sanitary Research Laboratory and Sewage Experiment Station has leased a building on the line of the largest main sewer, in which have been fitted up laboratories for chemical and bacteriological work, including a tank and filter house.



JOHN D. RUNKLE.

The institute has recently lost by death two of the original members of its faculty, whose portraits are here given. Professor John B. Henck was professor of civil engineering from 1865 to 1881. During this period he devoted himself largely to the work of teaching, but at this time and previously he also carried forward engineering works, the most important probably being the filling in and improvement of the Back Bay district of Boston. His 'Field Book for Railway Engineers,' published in 1854, and subsequently revised, passing through many editions, is a standard work. After retiring from his chair at the institute, Professor Henck settled in California and spent his life in retirement, dying early in the present year at the age of eighty-eight years. Professor John D. Runkle was professor of mathematics at the institute from 1865 until last year, when he was made professor emeritus. During this long period he was closely identified with the development of the institute, being always one of the leading members of the faculty and for a time presi-

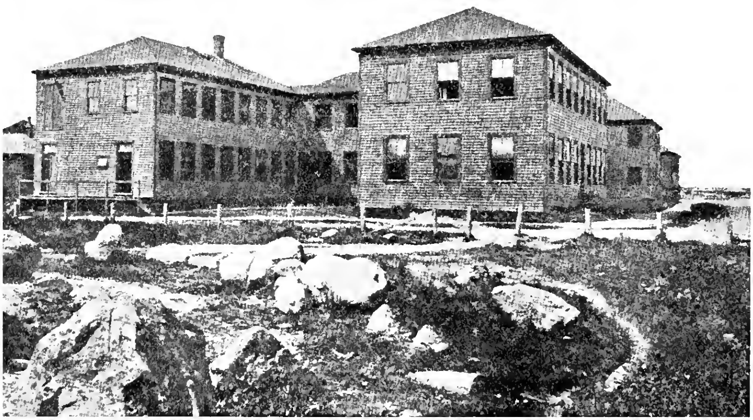


JOHN B. HENCK.

dent. Before he occupied this chair, he was engaged in the work of the Nautical Almanac, and founded *The Mathematical Monthly* in 1859. He took a prominent part in introducing manual training, not only in the institute, but also in the schools of the country.

SUMMER LABORATORIES AND SCHOOLS.

EDUCATION in America owes much to Louis Agassiz, and one of its greatest debts is the summer school of natural history established by him on the island of Penikese in 1873, the year before his death. The school did not long survive its founder, but it may be regarded as the beginning of the summer schools and laboratories which now play such an important part in the educational and scientific life of the country. Our college sessions have followed the precedent of Oxford and Cambridge in allowing long summer holidays. Formerly many of the students worked on the farm or otherwise during the summer months, and the heat of the season seemed to make natural a long vacation both in schools and colleges. But it seems to be no longer the case that college students commonly spend the long vacation in a profitable manner, and it has been discovered that teachers have in their holidays great opportunity for study and culture. The conditions have led to a complex and rather heterogeneous provision for education and research during the summer months. We have the Chautauqua movement, based mainly on religious interests, in which many denominations under one name or another have taken part. The school on Martha's Vineyard represented an extension of the teachers' institute, leading the way to the university summer schools. There have been schools for agriculture, for modern languages, for philosophy and of other kinds. But the two movements now the most wide-reaching and likely to be the most permanent are the laboratories of biology and the summer sessions of the universities.



BUILDINGS OF THE MARINE BIOLOGICAL LABORATORY, WOODS HOLE.

There are obvious reasons for pursuing the study of botany and zoology

during the summer season and by the seaside or some inland water. Thus can the needed material be obtained at the right time, and the collecting and exploring unite in the best possible manner study with healthful recreation. The general spirit of the laboratories is excellent; research is carried forward side by side with instruction, so that the dividing line is almost obliterated; there is a friendly spirit of cooperation and rivalry; things are known at first hand rather than darkly through books and lectures; the standard of living is simple; the follies and worse not uncommon in the colleges are lacking to a noticeable degree.

The Marine Biological Laboratory at Woods Hole may be regarded as the lineal descendant of Agassiz's school at Penikese, of which it has well maintained the traditions. The equipment has always been modest, as is shown by the accompanying photograph of the buildings, and perhaps this has not been a serious disadvantage. It is, however, hoped that sooner or later a fireproof building, which may be kept open in winter as in summer, will be erected. There are each year at Woods Hole between fifty and one hundred investigators carrying on original research, and about an equal number of students, many of whom become investigators. The Carnegie Institution has wisely decided not to acquire the laboratory, but is supporting it by contributing \$10,000 for twenty tables, and the laboratory is thus on a secure financial basis without loss of the independence and spirit of cooperation which have accomplished so much in the past. While the Woods Hole laboratory remains our chief center of biological research, rivaled only by Naples, other laboratories have been established along the Atlantic and Pacific coasts, at the Bahamas and on inland waters. Expeditions and camps of a temporary character should be mentioned in connection with the summer schools of natural history; practically all the geologists of the country are now in the field, and in many cases the parties consist of expert investigators accompanied by those who assist and learn.

The summer schools of the universities have not yet found their permanent basis, but there is no question as to the direction of their development and of the importance of the movement. A summer school once established is seldom abandoned and nearly always shows an increase in size and an improvement in quality from year to year. There are this summer over a thousand students at Harvard and at Columbia, and nearly twice as many at Tennessee. The students are largely teachers, but there are others of mature age, who wish to improve themselves. Then there are some regular students of the institutions—on the one hand, those so much interested in their work that they do not wish to lose the summer and, on the other hand, a few who need to 'make up conditions.' The instructing staff is also heterogeneous, there being usually some eminent lecturers and a good many young assistants. Chicago set the example of continuing its terms through the year, though in attempting to adjust its summer quarter to the needs of teachers, it has abandoned its original plan. We expect to see the university year ultimately divided into four quarters, with perhaps two weeks' vacation between each. The work of the summer term will be as 'regular' as any other, but as there will be fewer students an opportunity will be afforded to provide a special summer school for teachers. There are over 300,000 teachers in the country. It would be well if all schools would pay them a certain salary and in addition provide for their attendance at a summer school.

SCIENTIFIC ITEMS.

We regret to record the death of Professor W. C. Knight, professor of

geology and mining engineering in the University of Wyoming, and of Mr. William Earl Dodge, a merchant, known for his interest in educational and scientific institutions.

The University of London has conferred honorary degrees for the first time, the degrees of Doctor of Laws being given to the Prince of Wales, of Doctor of Music to the Princess of Wales and of Doctor of Science to Lord Kelvin and Lord Lister. It is said that the degree was offered to Mr. Herbert Spencer, but declined by him.—The Honorable Arthur Balfour, the British premier, has accepted the presidency of the British Association for the meeting to be held in Cambridge in 1904.—Sir W. Ramsay has been elected president of the Society of Chemical Industry. The society has decided to meet next year in New York City.

Dr. W J McGee has recently resigned his position in the Bureau of American Ethnology to take charge of the Department of Anthropology and Ethnology of the Louisiana Purchase Exposition.—Mr. Bailey Willis has accepted the position of leader of the Carnegie Geological Expedition to China, which has as its object the investigation of the Cambrian of that country.

The Desert Laboratory, being erected by an appropriation from the Carnegie Institution at Tucson, Arizona, is expected to be ready for occupancy on September 1, when Dr. W. A. Cannon, now assistant in the laboratory of the New York Botanical Garden, will become resident investigator.

The sixth International Congress of Psychology, which was to have met in Rome in the autumn of 1904, will be postponed to the spring of 1905 to avoid conflict with the sixth International Congress of Physiology which meets at Brussels in the autumn of 1904.

Mr. Carnegie's gift of $1,000,000 to the four national engineering societies and the Engineers' Club for a building has been accepted at a meeting of the representatives of the five organizations, and plans have been made for a joint committee consisting of three members from each organization. This committee will prepare plans for a building to be erected on Thirty-ninth Street. Efforts are being made to secure funds for the purchase of the land, and a number of subscriptions have been received by the American Institute of Electrical Engineers, including $5,000 from Dr. Elihu Thomson and the Westinghouse Electrical Company, $2,000 from Mr. Frank S. Sprague and $1,000 with a contingent $1,500 from Mr. J. G. White.

Chapters of the university scientific society of the Sigma Xi have recently been established at the Chicago and Michigan Universities. Chapters of this society are now maintained at the following universities: Cornell, V. A. Moore, president; Union, O. H. Landreth, president; Kansas, F. H. Snow, president; Rensselaer, W. P. Mason, president; Yale, J. P. Tracy, president; Brown, W. W. Bailey, president; Nebraska, L. Bruner, president; Minnesota, J. J. Flather, president; Iowa, T. H. McBride, president; Ohio, W. R. Lazenby, president; Pennsylvania, E. F. Smith, president; Stanford, V. L. Kellogg, president; California, C. L. Cory, president; Columbia, J. F. Kemp, president; Chicago, H. H. Donaldson, president; Michigan, J. P. McMurrich, president.

THE
POPULAR SCIENCE
MONTHLY.

OCTOBER, 1903.

THE DECORATIVE ART OF THE NORTH AMERICAN INDIANS.

By Professor FRANZ BOAS,
COLUMBIA UNIVERSITY.

THE extended investigations on primitive decorative art which have been made during the last twenty years have clearly shown that almost everywhere the decorative designs used by primitive man do not serve purely esthetic ends, but that they suggest to his mind certain definite concepts. They are not only decorations, but symbols of definite ideas.

Much has been written on this subject; and for a time the opinion prevailed that wherever an ornament is explained as a representation of a certain object, its origin has been in a realistic representation of that object, and that it has gradually assumed a more and more conventionalized form, which often has developed into a purely geometrical motive.* On the other hand, Cushing and Holmes have pointed out the important influence of material and technique in the evolution of design, and, following Semper, have called attention to the frequent transfer of designs developed in one technique to another. Thus, according to Semper, forms developed in wood architecture were imitated in stone, and Cushing and Holmes showed that textile designs are imitated on pottery.

The origin of certain designs from technical forms is now recognized as an important factor, and it must therefore be assumed that in many cases the interpretation has been read into the design. The existence of this tendency has recently been pointed out by H.

* See A. C. Haddon, 'Evolution in Art.'

Fig. 1a Eskimo in Ordinary Dress.

Schurtz* and by Professor A. D. F. Hamlin,† who has treated in a series of essays the evolution of decorative motives.

In speaking of the process of conventionalization or degeneration of realistic motives, Professor Hamlin says: "Indeed, this degeneration may reasonably be accepted as suggesting that the geometric forms which it approaches were already in habitual use when it began, and that the direction of the degeneration was determined by a

FIG. 1*b*. SHAMANISTIC COAT OF ESKIMO.

preexisting habit or 'expectancy' (as Dr. Colley March calls it) of geometric form acquired in skeuomorphic decoration" ‡ (*i. e.*, in a form developed from technical motives). At another place § he says: "After having undergone in its own home such series of modifications, the motive becomes known to the artists of some race or

* H. Schurtz, 'Urgeschichte der Kultur,' p. 540.

† *The American Architect and Building News*, 1898.

‡ *Ibid.*, p. 93.

§ *Ibid.*, p. 35.

civilization through the agency either of commerce or of conquest. It is carried across seas and lands, and in new hands receives still another dress in combinations still more incongruous with its original significance. It is no longer a symbol, but an arbitrary ornament, wholly conventional, modified to suit the taste and the arts of the foreigners who have adopted it. In many cases it undergoes modification in two or more directions, resulting in divergent developments, which in time produce as many distinct motives—cousins, as it were, of each other—each of which runs its own course independently of the others. This phenomenon we may call 'divergence.' A common cause of divergence is the tendency to assimilate a borrowed motive to some indigenous and familiar form, usually a natural object, thus setting up a new method of treatment quite foreign to the origin of the motive."

I intend to show in the following pages that the same processes, which Professor Hamlin traces by historical evidence in the art of the civilized peoples of the old world, have occurred among the primitive tribes of North America.*

Before taking up this subject, I wish to call attention to a peculiar difference between the decorative style applied in ceremonial objects and that employed in articles of every-day use. We find a considerable number of cases which demonstrate the fact that, on the whole, the decoration of ceremonial objects is much more realistic than that of ordinary objects. Thus we find the garments for ceremonial dances of the Arapaho covered with pictographic representations of animals, their sacred pipe covered with human and other forms, while their painted blankets for ordinary wear are generally adorned with geometrical designs. Among the Thompson Indians ceremonial blankets are also covered with pictographic designs, while ordinary wearing-apparel and basketry are decorated with very simple geometrical motives. On the stem of a shaman's pipe we find a series of pictographs, while an ordinary pipe shows geometric forms. Even among the eastern Eskimo, whose decorative art, on the whole, is very rudimentary, a shamanistic coat has been found which has a number of realistic motives, while the ordinary dress of the same tribe shows no trace of such decoration (Fig. 1). Perhaps the most striking examples of this kind are the woven designs of the Huichol Indians of

* The examples and illustrations here represented are taken, unless otherwise stated, from specimens in the American Museum of Natural History. The information and material used were collected by Dr. Roland B. Dixon, Professor Livingston Farrand, Dr. A. L. Kroeber, Dr. Berthold Laufer, Dr. Carl Lumholtz, Mr. H. H. St. Clair, Mr. James Teit and Dr. Clark Wissler, all of whom have contributed to the systematic study of decorative art undertaken by the museum.

Mexico. All their ceremonial weavings are covered with more or less realistic designs, while all their ordinary wearing-apparel presents geometrical motives. In fact, the style of the two is so different that it hardly seems to belong to the same tribe (Fig. 2). The same phenomenon may be observed outside of America, as is demonstrated by the difference in style between the shaman's coat and the ordinary coat of the Gold of the Amur River (Fig. 3). We may perhaps recognize the same tendency in the style of decoration of modern dwelling-rooms and in that of public buildings. The designs on the stained glass of house-windows are usually arranged in geometrical forms; those of churches represent pictures. The wall decorations of houses are wall papers of more or less geometrical character; those of halls devoted to public uses are generally adorned with symbolic pictures.

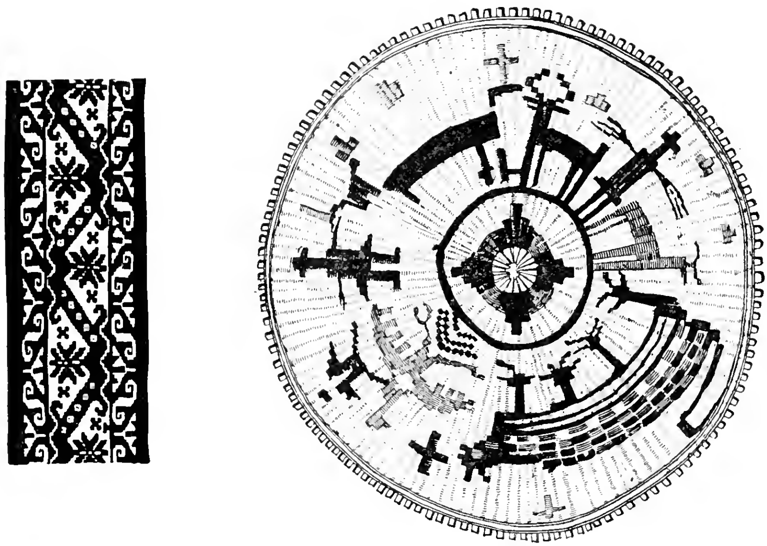


FIG. 2. WOVEN DESIGNS OF THE HUICHOL INDIANS. (After Dr. Carl Lumholtz.)

This difference in the treatment of ceremonial and common objects shows clearly that the reason for the conventionalization of motives can not be solely a technical one, for if so, it would act in one case as well as in the other. In ceremonial objects the ideas represented are more important than the decorative effect, and it is intelligible that the resistance to conventionalism may be strong; although in some cases the very sacredness of the idea represented might induce the artist to obscure his meaning intentionally, in order to keep the significance of the design from profane eyes. It may, therefore, be assumed that, if a tendency to conventionalization exists, it will manifest itself

differently, even among the same tribe, according to the preponderance of the decorative or descriptive value of the design.

On the other hand, the general prevalence of symbolic significance in ordinary decoration shows that this is an important aspect of decorative art, and a tendency to retain the realistic form might be expected, provided its origin were from realistic forms. If, therefore, the whole decorative art of some tribes shows no trace of realism, it may well be doubted whether their ordinary decorative designs were originally realistic.

FIG. 3a. ORDINARY COAT OF THE GOLD OF THE AMUR RIVER. (After Dr. Berthold Laufer.)

The history of decorative design can best be investigated by analyzing the styles of form and interpretation prevailing over a limited area. If the style of art were entirely indigenous in a given tribe, and developed either from conventionalization of realistic designs or from the elaboration of technical motives, we should expect to find a different style and different motives in each tribe. The general customs and beliefs might be expected to determine the subjects chosen for decoration, or the ideas that are read into the technical designs.

As a matter of fact, the native art of North America shows a very different state of affairs. All over the Great Plains and in a large portion of the western plateaus an art is found which, notwithstanding local peculiarities, is of a uniform type. It is characterized by the application of colored triangles and quadrangles in both painting and embroidery in a manner which is found in no other part of the world.

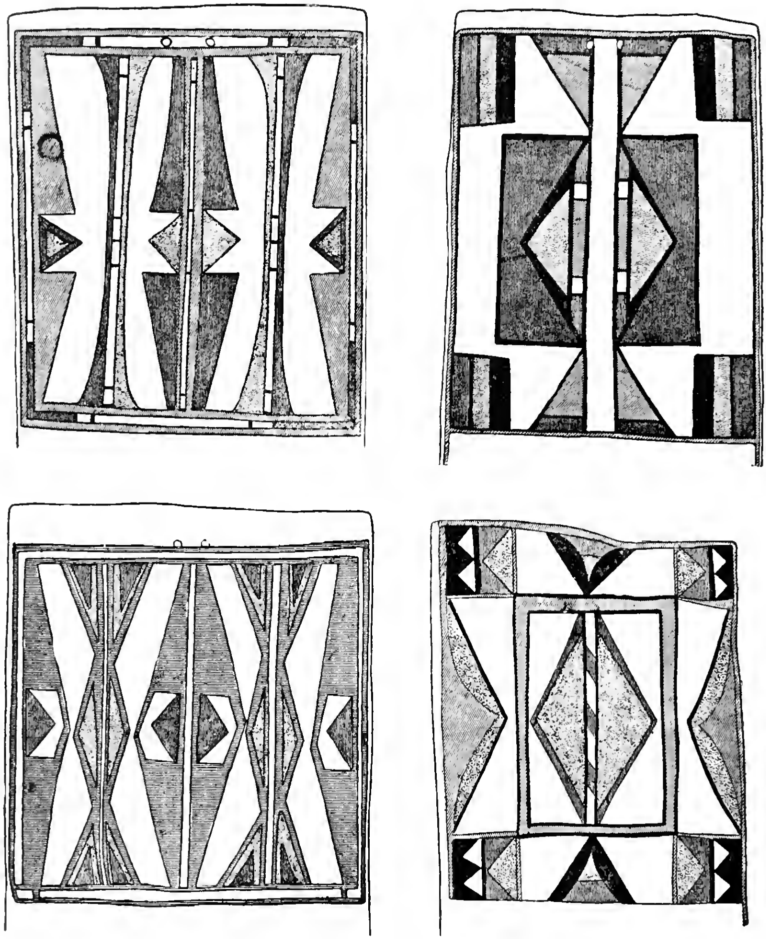
The slight differences of styles which occur are well exemplified in the style of painted rawhide bags or envelopes, the so-called 'parfleches.' Mr. St. Clair has observed that the Arapaho are in the habit of laying on the colors rather delicately, in areas of moderate size, and of following out a general arrangement of their motives in stripes; that the Shoshone, on the other hand, like large areas of

solid colors, bordered by heavy blue bands, and an arrangement in which a central field is set off rather prominently from the rest of the design (Fig. 4). This difference is so marked that it is easy to tell a Shoshone parfleche that has found its way to the Arapaho from par-

FIG. 3*b*. COAT OF A SHAMAN OF THE GOLD OF THE AMUR RIVER.

fleches of Arapaho manufacture. In other cases the most characteristic difference consists in the place on the parfleche to which the design is applied. The Arapaho and the Shoshone never decorate the sides of a bag, only its flaps, while the tribes of Idaho and Montana always decorate the sides. Another peculiarity of Arapaho parfleche-

painting, as compared to that of the Shoshone, is the predilection for two right-angled triangles standing on the same line, their right angles facing each other—a motive of common occurrence all over the southern part of the Plains and in the southwestern territories; while the Shoshone generally place these triangles with facing acute angles.



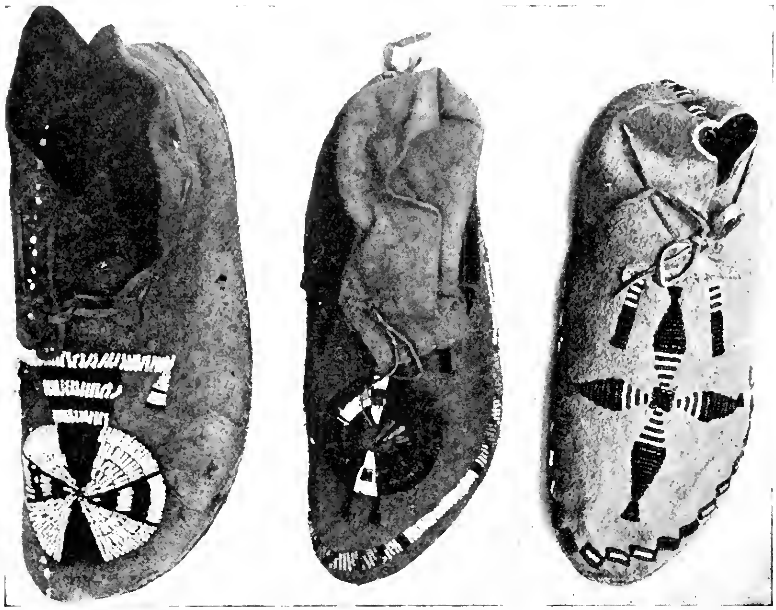
ARAPAHO. SHOSHONE.

FIG. 4. PAINTED RAWHIDE BAGS. (After A. L. Kroeber and H. H. St. Clair.)

A detailed study of the art brings out many minor differences of this sort, although the general type is very uniform.

Certain types of designs are so much alike that they might belong to one tribe as well as to another. A series of moccasins of the Shoshone, Sioux and Arapaho (Fig. 5) will serve as a good example. The characteristic forms of all of these are a cross on the uppers, con-

nected with a bar on the instep, from which arise at each end two short lines. These designs are so complex that evidently they must have had a common origin. It is of great importance to note that nevertheless the explanations given by the various tribes are quite different. The design is interpreted by the Arapaho as the morning star; the bar on the instep, as the horizon; the short lines, as the twinkling of the star. To the mind of the Sioux the design conveys the idea of feathers, when applied to a woman's moccasin; when found on a man's moccasin, it symbolizes the sacred shield suspended from tent-poles. The identical design was explained by the Shoshone



A *B* *C*

FIG. 5. MOCCASINS; *A*. SHOSHONE; *B*. SIOUX; *C*. SIOUX AND ARAPAHO.

as signifying the sun (the circle) and its rays; but also the thunder-bird, the cross-arms of the cross evidently being the wings; the part nearest the toe, the tail, and the upper part, the neck with two strongly conventionalized heads attached. If these are the ideas conveyed by this design to the weavers, it is clear that they must have developed after the invention or introduction of the design; that the design is primary, the idea secondary, and that the idea has nothing to do with the historical development of the design itself.

It may be well to give a few additional examples of such similarity of design and difference of symbolism. One of the typical designs

of this area is a cross to the ends of which deeply notched squares are attached (Fig. 6). Dr. Kroeber* received the following explanation of this design from an Arapaho: the diamond in the center represents a person: the four forked ornaments surrounding it are buffalo hoofs or tracks. Dr. Wissler found the design on a pair of woman's leggings of the Sioux. In this case the diamond-shaped center of the design represents the breast of a turtle; the green lines forming the cross indicate the four points of the compass; the forked ornaments symbolize forks of trees struck by hailstones, which are indicated by small white rectangles. Mr. St. Clair came across the same design among the Shoshone, where it was found on a cowhide bag. The central diamond was interpreted as the sun and clouds; the notched designs were explained as mountain-sheep hoofs. There is a certain similarity in this case between the explanations given by the Arapaho and those of the Shoshone, while the Sioux connect ideas of a different type with the design.

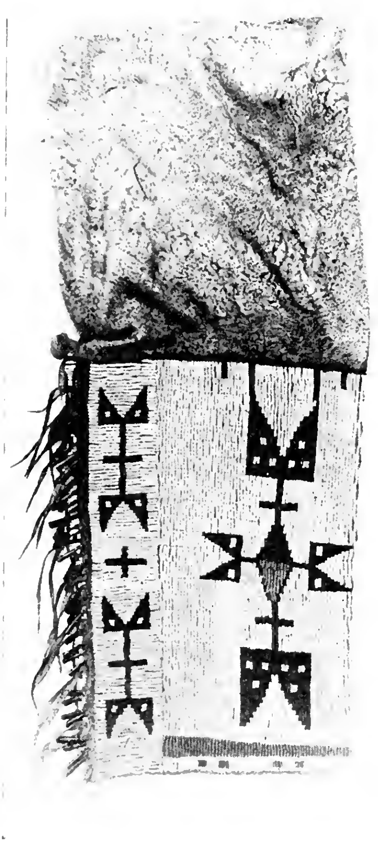


Fig. 6. Legging with Bead Embroidery.

Such differences of interpretation are also found on painted designs. The Shoshone sometimes imagine they see a battle scene in the squares and triangles of their parfleche designs. The square in the center of Fig. 7 was explained to Mr. St. Clair as an enclosure in which the enemy was kept by a besieging party, represented by the marginal squares. The narrow central line is the trail by which the enemy made good his escape. Many others represent geographical features, such as mountains and valleys. Such geographical ideas are represented on some Arapaho parfleches, while others exhibit a more complex symbolic significance. Battle scenes, however, are not found in interpretations given by the Arapaho.

* A. L. Kroeber, 'The Arapaho,' *Bulletin American Museum of Natural History*, Vol. XVIII.

The similarity of complex designs, combined with dissimilarity of interpretation, justifies a comparison of simpler forms. These might be believed to have originated independently; but the sameness of the complex forms proves that their component elements must have had a common origin, or at least have been assimilated by the same forms. One of the striking examples of this kind is the cross. Among the Arapaho it signifies almost invariably the morning star. To the mind of the Shoshone it conveys the idea of barter. The Sioux recognizes in it a man slain in battle and lying flat on the ground with arms outstretched. The Thompson Indians of British Columbia recognize in it the crossing trails at which sacrifices are made.

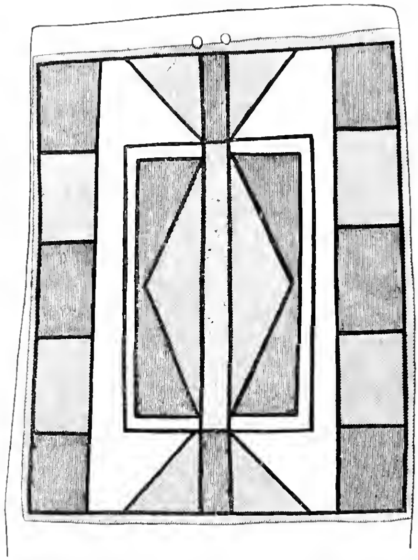


Fig. 7. Shoshone Parfleche Design.

The simple straight red lines with which skin bags are decorated are another good example. A specimen was collected by Dr. Kroeber among the Arapaho (Figs. 8a and 8b) in which he explains the stripes on the beaded design on the narrow sides and on the flaps of the bag as camp-trails; the shorter transverse stripes intersecting these longitudinal lines, as ravines, that is, camping-places. On the front of the bag the horizontal lines of quill-work, which resemble the lines on buffalo-robes, are paths. Bunches of feathers on these lines represent buffalo-meat hung up to dry. Adjoining the bead-work are small tin cylinders with tufts of red hair; these represent pendants or rattles on tents. Mr. St. Clair obtained the following explanation of a Shoshone bag of almost identical design: The porcupine-quill work on the front of the bag represents horse-trails. The red horsehair tassels at each side are horses stolen by people of one village from those of another, the villages being represented by the bead-work at the sides of the bag. The bead-work on the flap represents the owners of the horses indicated by the horse-hair tassels on the flap. Among the Sioux the same design is used in the puberty ceremonial, and symbolizes the path of life.

It must not be believed that the interpretation of a certain motive, or even of a complex figure when used by the members of one tribe,

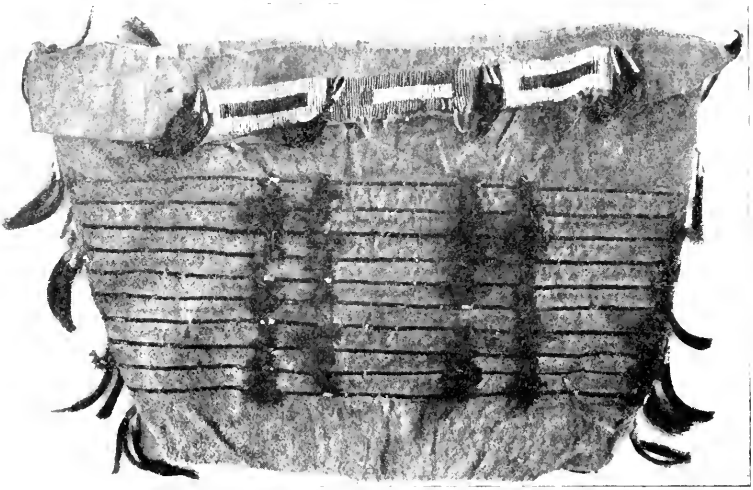


FIG. 8*a*. SKIN BAG OF THE ARAPAHO. (After A. L. Kroeber.)

is always the same. As a matter of fact, the number of ideas expressed by it is often quite varied. We find, for instance, the obtuse triangle with enclosed rectangle (Fig. 4) explained by the Arapaho as the mythic cave from which the buffalo issued, as cattle-tracks, as a mountain, cloud, brush hut and tent; an acute triangle, with small triangles attached to its base, as a bird-tail, frog, tent and bear-foot.

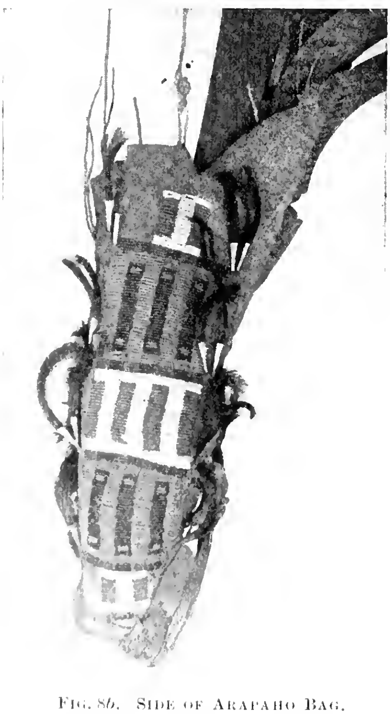


FIG. 8*b*. SIDE OF ARAPAHO BAG.

Nevertheless the explanations given by various tribes show peculiar characteristics in which they differ from those of other tribes. The explanations possess no less a style of their own than the art itself. Triangles are explained as tents by all the tribes, and mountains or hills form a prominent feature of their descriptions; but among the three tribes mentioned only the Sioux see wounds, battle scenes with moving masses of men, horses, the pursuit of enemies, the flight of arrows, in their conventional de-

signs; only the Shoshone see in them pictures of forts and stones piled up in memory of battles; only the Arapaho recognize in them prayers for life directed to the morning star.

We find, therefore, that in this area the same style of art is widely distributed, while the style of explanation differs materially among its various tribes.

It may be worth while to review briefly the distribution of the style of art here discussed. On the whole, it is confined to the Plains Indians, west of the eastern wooded area. It would seem that it has been carried into the plateau region rather recently, where, however,

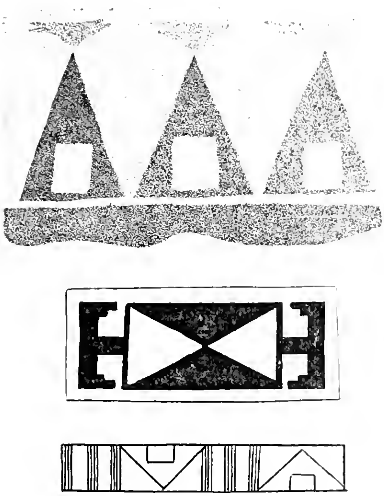


Fig. 9. Decorative Motives of the Pueblo Indians. (After Dr. W. F. Fewkes.*)

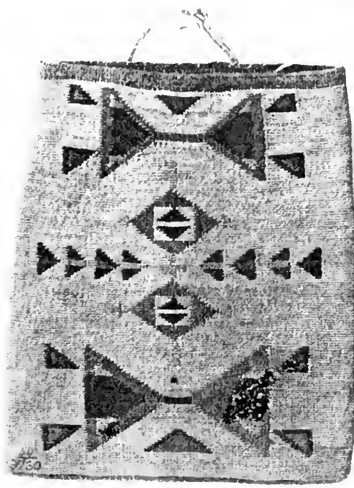


Fig. 10 Woven Bag of the Nez Percés.

it has affected almost all the tribes east of the Cascade Range and of the Sierra Nevada. We find the acute triangle with small supporting triangles, and the obtuse triangle with enclosed rectangle, in the characteristic arrangement of the parfleches, on a bag of the Nez Percés (Fig. 10) collected by Dr. Livingston Farrand. At first glance, the art of the Pueblos seems quite different from the one that we are discussing here; but I believe that an intimate association of the two may be traced. The old pottery described by Dr. Fewkes, for instance, shows a number of the peculiar triangle and square motives which are so characteristic of the art of the Indians of the Plains. The same triangle with supporting lines, the same triangle with the enclosed square (Fig. 10), is found here. It seems very plain to my mind that the transfer of this art from pottery to embroidery and painting on flat surfaces has brought about the introduction of the triangular

* From specimens in the U. S. National Museum.

and rectangular forms which are the prime characteristic of this type of art.

In the prehistoric art of the northern plateaus, in California, on the North Pacific coast, in the Mackenzie Basin, in the wooded area of the Atlantic coast, we find styles of art which differ from the art of the Plains, and which have much less in common with Pueblo art. Therefore I am inclined to consider the art of the Plains Indians in many of its traits as developed from the art of the Pueblos. I think the general facts of the culture of these tribes are fairly in accord with this notion, since it would seem that the complex social and religious rites of the southwest gradually become simpler and less definite as we proceed northward. If this opinion regarding the origin of the art of the Plains is correct, we are led to the conclusion that the tent with its pegs is the same form in origin as the rain-clouds of the Pueblos, so that the scope of interpretations of the same form is still more enlarged. Under these conditions, we must conclude that the interpretation is probably secondary throughout, and has become associated with the form which was obtained by borrowing. With this we are brought face to face with the skeuomorphic origin of the triangular design from basketry motives, which has been so much discussed of recent years.

The so-called 'quail-tip' design of California is another example of the continuous distribution of a motive over a wide area, the occurrence of which in the outlying districts must be due to borrowing. The characteristic feature of this design, which occurs in the basketry of California and Oregon, is a vertical line, suddenly turning outward at its end. This motive occurs on both twined and coiled basketry, and with many explanations.* In some combinations it is explained as the lizard's foot (Fig. 11, *a*, *b*), in others as the pine cone or the mountain (Fig. 11, *c*). The gradual distribution of this motive over a wide area can best be proved in this case by a comparison with the distribution of the technique in which it is applied. The design occurs all over central and northern California. On Columbia River it is found on the Klickitat baskets. These are of the peculiar imbricated basketry which is made from this point on, northward. While the designs on imbricated basketry found in British Columbia are of a peculiar character, the Klickitat baskets of the same make (Fig. 11, *d*) have the typical California designs which also occur on the twined bags of this district (Fig. 11, *e*).

Thus we find, not only that the distribution of interpretations and that of motives do not coincide, but also that the distribution of technique does not agree with that of motives. I think we can also demon-

* Roland B. Dixon, 'Basketry Designs of the Indians of Northern California,' *Bulletin American Museum of Natural History*, Vol. XVII., pp. 2 ff.

strate that the limits of styles of interpretation in some cases overlap the limits of styles of art. We have seen that on the Plains the style of art covers a wider area than the style of interpretation. It would seem that in other regions the reverse is the case. For instance, the style of art of the Nootka tribes differs very much from that of the

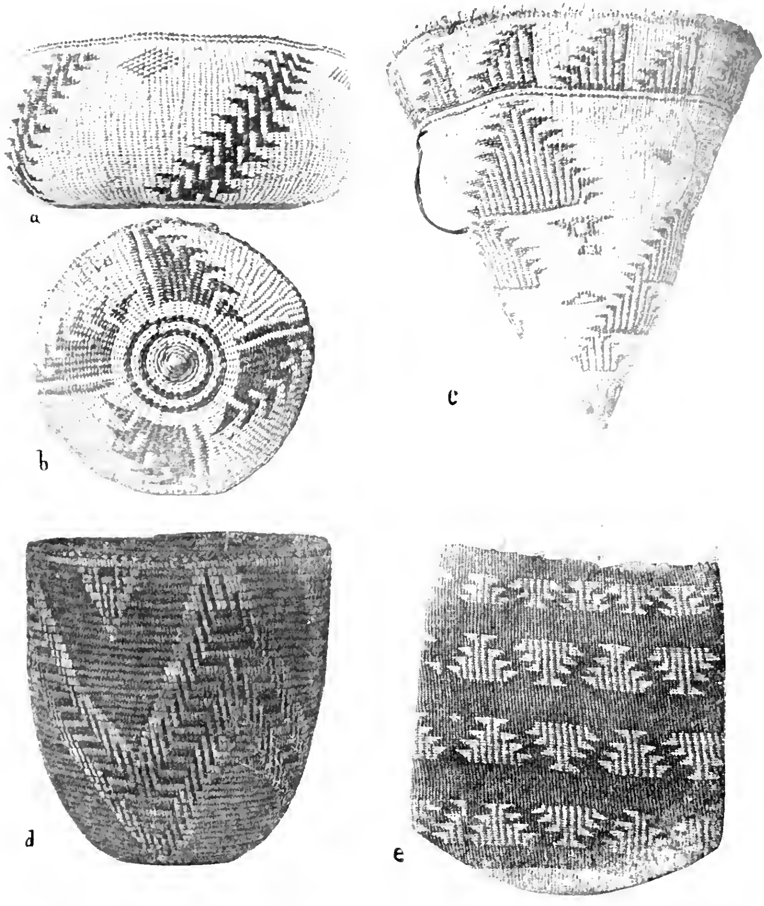


FIG. 11. BASKETS FROM THE PACIFIC COAST. *a*, *b*, PIT RIVER, CALIFORNIA; *c*, MAIDU, CALIFORNIA; *d*, KLICKITAT, WASHINGTON; *e*, NEZ PERCÉS, IDAHO. (*a*, *b* and *c* after Dr. Roland B. Dixon.)

Kwakiutl. Although both apply animal motives, the Nootka use very little surface decoration consisting of combinations of characteristic curved lines, which play an important part in Kwakiutl art, and which serve to symbolize various parts of the body. Nootka art is more realistic and at the same time cruder than Kwakiutl art. The ideas expressed in the art of both tribes, however, are practically the same. In the southwest we find that the culture of the Pueblos has

deeply influenced the neighboring Athapascan and Sonoran tribes, while at the same time the decoration of their basketry bears a close relation to that of Californian basketry. Although I do not know the interpretations of designs given by the Apache, Pima and Navajo, it seems probable that they have been influenced by the ideas current among the Pueblos. Among the Pueblos themselves—and in these I include the tribes of northern Mexico, such as the Huichol—there are well-marked local styles of technique and of decoration, and a general

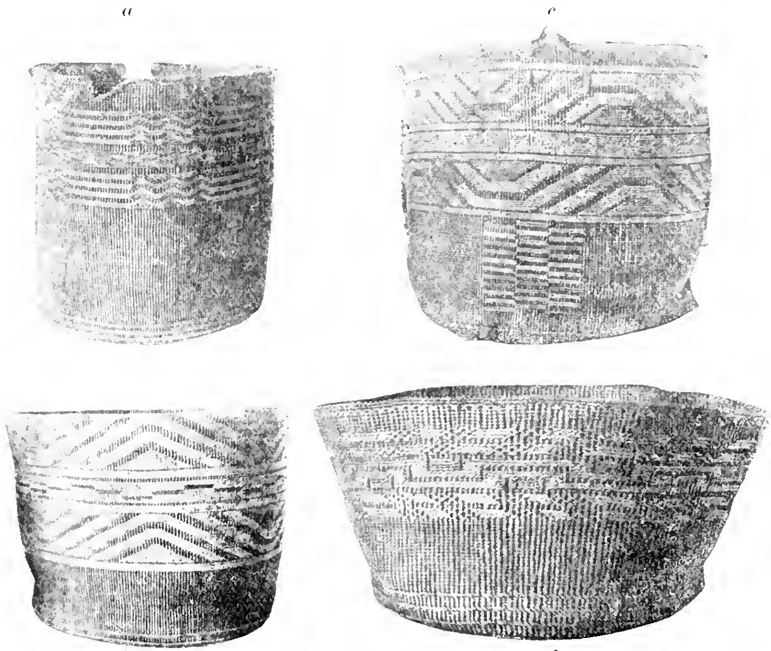


FIG. 12. TLINGIT BASKETS. (Specimens in the possession of G. T. Emmons.)

similarity of interpretation. I think the marked prevalence of geographical interpretations found among the Salish tribes of British Columbia, the Shoshone and the Arapaho is another instance of distribution of a style of interpretation over an area including divers styles of art.

In a few cases it seems almost self-evident, from a consideration of the interpretations themselves, that they can not have developed from realistic forms. The multiplicity of Arapaho explanations for the triangles which I mentioned before suggest this. According to G. T. Emmons,* the zigzag and the closely allied meander in Tlingit basketry have a variety of meanings. The zigzag may represent the

* 'The Basketry of the Tlingit,' *Memoirs American Museum of Natural History,* Vol. III., pp. 263 ff.

tail of the land-otter (Fig. 12, *a*), the hood of the raven (Fig. 12, *b*), the butterfly (Fig. 12, *c*), or, when given a rectangular form (Fig. 12, *d*), waves and floating objects. It is evident, in view of the data here discussed, that these must be different interpretations of motives of similar origin.

We conclude from all this that the explanation of designs is secondary almost throughout and due to a late association of ideas and forms, and that as a rule a gradual transition from realistic motives to geometric forms did not take place. The two groups of phenomena—interpretation and style—appear to be independent. We may say that it is a general law that designs are considered significant. Different tribes may interpret the same style by distinct groups of ideas. On the other hand, certain groups of ideas may be spread over tribes whose decorative art follows different styles, so that the same ideas are expressed by different styles of art.

We may express this fact also by saying that the history of the artistic development of a people, and the style that they have developed at any given time, predetermine the method by which they express their ideas in decorative art; and that the type of ideas that a people is accustomed to express by means of decorative art predetermines the explanation that will be given to a new design. It would therefore seem that there are certain typical associations between ideas and forms which become established, and which are used for artistic expression. The idea which a design expresses at the present time is not necessarily a clew to its history. It seems probable that idea and style exist independently, and influence each other constantly.

For the present it remains an open question, why the tendency to form associations between certain ideas and decorative motives is so strong among all primitive people. The tendency is evidently similar to that observed among children who enjoy interpreting simple forms as objects to which the form has a slight resemblance; and this, in turn, may bear some relation to the peculiar character of realism in primitive art, to which I believe Von den Steinen* was the first to draw attention. The primitive artist does not attempt to draw what he sees, but merely combines what are to his mind the characteristic features of an object, without regard to their actual space relation in the visual image. For this reason he may also be more ready than we are to consider some characteristic feature as symbolic of an object, and thus associate forms and objects in ways that seem to us unexpected.

It may be worth while to mention one general point of view that is suggested by our remarks. The explanations of decorative design

* 'Unter den Natur-völkern Central-Brasiliens,' pp. 250 ff.

given by the native suggest that to his mind the form of the design is a result of attempts to represent by means of decorative art a certain idea. We have seen that this can not be the true history of the design, but that it probably originated in an entirely different manner. What is true in the case of decorative art is true of other ethnic phenomena. The historical explanation of customs given by the native is generally a result of speculation, not by any means a true historical explanation. The mythical explanation of rites and customs is seldom of historical value, but is generally due to associations formed in the course of events, while the early history of myths and rite must be looked for in entirely different causes, and interpreted by different methods. Native explanations of laws, of the origin of the form of society, must have developed in the same manner, and therefore can not give any clew in regard to historical events, while the association of ideas of which they are the expression furnishes most valuable psychological material.

HIGHWAYS AND BYWAYS OF ANIMAL LIFE.

By Professor HERBERT OSBORN,
OHIO STATE UNIVERSITY.

No matter what particular theory he may hold as to the origin and distribution of life over this globe of ours, the thoughtful naturalist or the thoughtful student in any sphere of research, if he stops to question at all, must ponder with deepest interest the problems connected with the wide dispersal of animal life and its adaptations to most diverse conditions. From darkest depths of abyssal ocean to lofty mountain peak, life abounds and even the high regions of ethereal air are traversed by one or another of the organisms which represent the great aggregate of animal life.

It is true that these limits, viewed from a certain standpoint, are very narrow, for a moment's consideration will reveal the fact that life on this sphere now, as in all time past, is confined to a comparatively thin stratum at its surface. From the deepest habitable reaches of ocean to the highest point attainable by bird (a few miles, indeed, of vertical elevation) is a slight range in the radius of the earth, and the densely populated stratum of land and sea—the stratum actually capable of supporting life continuously is, in reality, limited to a very few feet—an exceedingly thin layer on a gigantic ball. One almost trembles at the thought of how narrow the habitable limits and how slight a change in conditions of atmospheric or other physical environment might extinguish the vital spark which has characterized mother earth through untold stretches of years. Consider a moment how little below the surface any animal can live, how slightly above it is existence possible.

But my purpose here is to touch upon some of the routes of development of the shifting forms of animal life which have drifted hither and thither over sea and land in the great struggle for perpetuity and expansion.

This effort we can clearly see in the movement taking place under our own eyes, and, more largely, within historic times, as evidenced by the host of animals introduced and spread in the new world from the old, the displacement or extinction of certain forms and perhaps most emphatically in man himself, the dominant animal of the present age, whose struggle has now become not so much a struggle with other species as a struggle for dominance of race over race, or nation

over nation. Glancing backward, however, over that long and varied line of animal life shown to us in fossil forms—their history incontestably preserved for us direct from the hand of creation, we must readjust our vision, enlarge our horizon to grasp the significance of the origin, distribution, adaptation and survival of life. Life is here—life has been a feature of this old earth's history through countless ages. Whence came it, what have been the paths it has followed in its development and adaptation to the varied conditions of earth, sea, land and air? It would be presumption too gross to admit of toleration to assume to fully discuss so extensive a problem within the limits of a magazine article, but an effort will be made to point out in a rapid survey some of the factors that seem to have been effective in the peopling of the earth.

First, we should observe the conditions that have existed and that had to be met in the growth of organic beings—for we should not forget that life has had to adjust itself to conditions that existed prior to its appearance, since the conditions have not been modified to accommodate its needs.

Stretches of water and great reaches of land and the atmosphere furnish the basis upon which organisms must act, and either water or air, the medium that must serve them for many of their most vital functions. Glancing over the opportunities for survival of life in a delicate, simple condition, we can hardly fail to recognize the water as the most natural element for primal life-forms. Indeed, I think no naturalist will hesitate to consider water or, at least, an extremely moist location as the necessary condition for the beginning of life. Moreover, any serious consideration of the question must force the conviction that life-forms in other less favorable locations must have reached such location by gradual modification and adaptation. For instance, we can hardly conceive of the peopling of an arid desert-region with forms such as lizards, snakes, horned toads, scorpions, beetles, etc., except by the gradual encroachment upon desert area from adjacent territory by animals which were able to adapt themselves to desert conditions. Or, to put it in another form, the change to desert conditions in previously watered area must be accompanied by the driving out or extinction of all animals unable to adjust themselves to the new conditions. Assuming, then, a primary aquatic habitat for animal life, it becomes of interest to inquire both as to the most probable point of origin and as to the direction of adaptations.

While some naturalists argue for a pelagic origin of the simplest organisms, others hold to the idea of an origin near the shore, but in either case we have evident lines of travel from such a point to occupy the surrounding space. Thus from a near shore location life might work itself shoreward, adapting itself to the variable conditions of ebb

and flow of water and exposing itself to such variations of conditions as might lead to fresh-water existence—to life on the land and thence to air, and, on the other hand, a dispersal on the surface to pelagic life. Again from shore-life or the original near-shore location. there might be a contingent working into deeper seas, and still further to occupation of abyssal depths. Transfers from surface to sea bottom, and the reverse, seem probable, in fact certain, for some groups and movements of terrestrial groups of animals into water must certainly have taken place. The peopling of all habitable corners of the earth then has been a process of continual pushing out from original centers, a constant, if unconscious, effort of animal life as a whole to occupy all available space, to crowd the energy of vital force to the end of every open channel, to follow every thoroughfare and explore every by-path that might lead to nook or corner in the universe that could give support in any fashion. But seldom has any form of life started alone on its travels, and hence the crowding for place, the 'pussy wants a corner' need, the eternal jostling to get and keep that corner and its opportunities, the 'struggle for existence' that has been the dominant principle of life from the dawn of its creation. Clearly those forms most successful in adaptation to new conditions must be those that win in the race and which soonest give rise to a higher and more complex form of existence. Whether life began in a single organism the parent form for all the mighty train that followed until now, or whether numerous organisms started independently, we can hardly doubt that all were equally simple, and similar courses of modification must have affected all. Moreover, in every case, we are warranted in assuming that for all higher types of animals there was a probably common ancestral form, and distribution over the earth must have been accomplished from an initial center by succeeding generations. Further, that for each particular subordinate group, family, genus or species that now has extended distribution, we must assume dispersal from the original home of the ancestral form.

First, then, we had only aquatic life, and this element may have been densely peopled before an effort was made to move ashore or to seek dry land. All geological evidence shows enormous development of aquatic life in early times, but obviously such forms were most likely to be preserved. Land life may have been forced by the drying up of stretches of water as well as voluntary migration. But what an important change that from aquatic to terrestrial life—from water-breathing to air-breathing! What possibilities of expansion, growth and occupation in the new, untrodden sphere, in the valleys and hills of earth and in the invigorating supply of air! Up this highway have come not a few of the great groups of animals. Some of the simplest protozoans even discovered the track, and worms of various kinds have crawled to

wider or sometimes to narrower possibilities. Mollusks took advantage of the path, and many of them have reached even to life arboreal, while some, apparently disheartened or diverted by seductive opportunities, have gone back to water, still retaining, however, their air-breathing organs to prove the roundabout course of their travels.

The ancestral forms of insects doubtless followed the same broad way, but so remote are these ancestors that we may best consider the insects as primitively air-breathing. Some indeed are now aquatic, but still air-breathers, and I doubt not have taken to aquatic life as a fairly modern accomplishment. Vertebrates, however, give us the greatest advance, for from the gilled fish, and early amphibian, to bird or mammal is a long and striking course. If any branch of animals is to be thought of as having had its origin on land rather than in water, it must be the insects, that is, the immediate ancestral form to all the groups of insects. Following back their ancestral line still further we should doubtless reach an aquatic animal, but one not to be recognized as in any degree insect-like in character.

But life in the open air has not confined itself to particular places or conditions. The pressure to occupy each niche of available territory is as strong here as in the water. Here too we may trace certain well-worn paths—paths that have been common to more than one group of animals and traveled independently by each. Let us mention some —subterranean, aquatic, terrestrial, arboreal, aerial. How many forms in hosts of different groups have buried themselves more or less completely in mother earth and there found, or made for themselves, all the necessary conditions for successful life. Earthworms, crustaceans, insects too numerous to mention, mollusks and, among vertebrates, frogs, snakes, lizards, turtles, birds, moles, beavers, gophers, groundhogs, badgers, etc. This for the general trend, many of these, however, taking peculiar and tortuous by-paths to reach the end desired. From terrestrial back to aquatic life has been so frequent a course that we can hardly call the road exceptional. So many insects of different groups have become aquatic in either adult or larval life that it was long held that the insects in general were derived from these aquatic groups. None, I think it safe to say, has had such an immediate ancestry, while aquatic beetles, bugs, caterpillars and even dragonflies, caddiceflies, etc., have, I firmly believe, gradually assumed aquatic habits as descendants of forms that lived on land.

We can easily believe that frogs advanced from an aquatic to a terrestrial condition, because we can actually see the process in the individual history of each, but there is reason to believe that even among certain batrachians aquatic life becomes more habitual and succeeds a terrestrial stage. Even the frog himself becomes decidedly aquatic in his old age, and for reptiles, while we often think of them as aquatic,

especially such forms as the alligator and crocodile and the ancient marine saurians, in reality we should think of them as primarily land-inhabiting animals, some of which have gradually taken to aquatic life and in the course of time become more and more confined to a watery sphere. Aquatic turtles show this most decidedly, an extreme being found in the soft-shelled turtle, which is not only a constant resident in water, but has become possessed of special organs for respiration in water, so that air-breathing is scarcely necessary. Birds that live in the water have taken the same convenient highway, and many of them have traveled it from the time of their toothed ancestors down to the present. Penguins have gone so far along this road that their wings can no longer serve for flight, while loons and grebes and auks are on the way. Gulls, albatrosses and petrels may go far out o'er billowy wave hundreds of miles from land. Ducks and geese and swans have struck the trail, and snipe, stork and heron, crane and flamingo have rolled up their trousers and are wading in. Even the fish-hawk, the osprey and the eagle find it worth while to look beneath the wave.

The aquatic habits of the beaver furnish a most remarkable example of this, and if we could trace his acquisition of this habit from the time when he must have been an ordinary terrestrial rodent with neither a paddle-tail nor a web foot, we should certainly find an interesting career. The musk-rat has not gone so far and can not reach the same goal, as he has flattened his tail in the wrong direction.

The whale—that giant of the seas—largest of mammals and indeed of all animals, has out-traveled all his relatives in reaching out into the great ocean, but we can not possibly conceive the whale to have come from any other source or to have other ancestor than a land-inhabiting mammal. We get glimpses of the mile posts he has passed in the structures shown by the manatee, the walrus, the sea lions and others. Not that these constitute in any sense his ancestral line, for that was far back in time and so far largely a lost history. But along such stages we must believe his ancestors to have passed. The manatee in its way is as strictly aquatic as the whale but hugs the shore or river mouths.

The hippopotamus is well on the way, and I would digress here to call attention to the remarkable similarity in adaptation of the sense organs of this animal to those of the alligator and crocodile. Note that the eyes, ears and nostrils are almost exactly in the same plane and so situated that they may all be above the surface of the water, while practically no part of the head or body may be visible, an admirable adjustment to avoid detection from foes or for protection against flies, mosquitoes, etc. Seals, walruses, sea lions, sea otters and, in less degree, the polar bear, the common otter and mink, all show aquatic habit fixed or growing, and even the small boy at his favorite swim-

ming hole presents a tendency to fall into the well-worn path that leads down to amphibious quarters.

On the broad highway of terrestrial life the effort and adaptation has been to develop speed, strength, protective coverings, colors, etc., and here has been the widest and strongest struggle for supremacy that the world has witnessed. The contest for domination between the giants of old ocean—of sharks and devil-fishes, and saurians and whales, pales into insignificance compared with the battle waged between the huge terrestrial reptiles, birds, elephants, mastodons, horses, lions and man which has raged on *terra firma*. From this have come perfection of speed to one—power and energy to another, but, above all, intelligence and the dominance of brain. Out of this highway, too, run numerous and devious by-paths, the following of which furnishes us with a host of strange and fanciful creations—adaptations to extremes of heat and cold, moisture and dryness, latitude and altitude, plain and forest.

But, not content with solid earth, animal life finds its way upward into vegetation of various kinds and particularly in tree growth, reaches adaptations which become so fixed that life elsewhere would be an impossibility. This is especially marked in the great tangle of tropical forests. In these the animal life of the tree tops assumes a most pronounced character, which can scarcely be appreciated by one familiar only with lesser forests of temperate regions. Pictures fail to show the real density, for pictures must show the breaks and gaps to show at all. But perhaps the most dominant thought in the presence of such forest life is the superabundance of life, life everywhere, under every scrap of loose bark, every tuft of grass, on branch, and twig and leaf. In my despair of giving an adequate idea of this tropical tangle, I turn to an article in *Harper's Magazine* by Lafcadio Hearn on a midsummer trip to the West Indies, in which he quotes from DeRafz:

When your eyes grow weary—if it is indeed possible for them to weary of contemplating the exterior of these tremendous woods, try to penetrate a little way into their interior. What an inextricable chaos it is! The sands of the sea are not more closely pressed together than the trees are here—some straight, some curved, some upright, some toppling, falling, or leaning against one another, or heaped high upon each other. Climbing lianas, which cross from one tree to the other, like ropes passing from mast to mast, help to fill up the gaps in this treillage; and parasites—not timid parasites like ivy or moss, but parasites that are grafted upon trees—dominate the primitive trunk, overwhelm them, usurp the place of their foliage and fall back upon the soil forming factitious weeping willows. You do not find here as in the great forests of the north, the eternal monotony of beech and fir; this is the kingdom of infinite variety—species, the most diverse, elbow each other, interlace, strangle each other and down them. All ranks and orders are confounded as in a human mob.

> As for the soil it is needless to think of looking at it; it lies as far below us as the bottom of the sea; it disappeared ever so long ago, under the heaping of débris, under a sort of manure that has been accumulating there since creation; you sink into it as into slime; you walk upon petrified trunks in a dust that has no name. Here indeed it is that one can get some comprehension of what vegetable decrepitude signifies; a lurid light—as wan at noon as the light of the moon at midnight, confounds forms and lends them a vague and fantastic aspect; a mephitic humidity exhales from all parts; an odor of death prevails; and a calm which is not silence (for the ear fancies it can hear the great movements of composition and decomposition perpetually going on within) tends to inspire you with the old mysterious horror which the ancients felt in the primitive forests of Germany and Gaul.

Hearn adds:

> But the sense of awe inspired by the view of a tropical forest is unutterably greater than any mystical fear which any wooded wilderness of the north could ever have inspired. The very brilliancy of these colors—that seem preternatural to northern eyes—is terrifying; but the vastness of the mile-broad and mile-high masses of frondage, their impenetrability, the violet blackness of the few rare apertures in their perpendicular façades where mountain torrents break through to the sun, and their enormous murmurs, made up of a million crawling, creeping, crumbling sounds—all combine to produce the conception of a creative force that appalls. Man feels here like an insect, fears like an insect ever on the alert for merciless enemies. To enter these green abysses without a guide were madness; even with the best of guides it is perilous. Nature is dangerous here; the powers that build here are also the powers that putrefy. Here life and death are perpetually interchanging office in the never-ceasing transformation of force, melting down and reshaping living substances simultaneously within the same awful crucible. There are trees distilling venom; there are plants that have fangs; there are perfumes that affect the brain; there are cold green creepers whose touch consumes the flesh like fire, while in all the recesses and the shadows is a swarming of unfamiliar life, beautiful or hideous, insect, reptile, bird, interwarring, drowning, devouring, preying. Strange spiders of burning colors, immense lizards, scaribs cuirassed in all tints of metal, humming-birds plumaged in all splendor of jeweled radiance, flies that flash like fire, centipedes of gigantic growth. And the lord of all these, the despot of these vast domains is the terrible Fer de lance. . . .

Here, then, is unlimited food, abundant moisture, warmth and light, and no wonder animal life has grown apace, multiplied and modified its form—and adapted itself to forest conditions.

Along this forest route come certain strange, peculiar molluscs, which far from the native haunts of their allies have succeeded in establishing themselves in apparently successful occupation against more active forms. Insects, unnumbered, occupying every part from solid wood of the tree heart to outermost bark or leaf, a few fishes even leave their water haunts for temporary quarters up a tree, and frogs are here to stay, while snakes, lizards, chameleons, are at home awaiting callers. To birds the trees become a most natural harbor and home to rest, to nest, to eat and die. Ungainly sloths, helpless elsewhere,

are at home in the tree tops; and squirrels, opossums, coons, bears, cats, monkeys, apes, and sometimes man, find up among the branches of a tree the situation that meets pleasure or necessity.

Launching out into the air, the most difficult path to take, most hazardous and most perilous, but attempted by many different kinds of animals, is another highway. Some faint suggestion of an effort to utilize the air in locomotion is shown by the wind-blown Portuguese man-of-war, and more fully by the aeronautic spider who launches his balloon of silk for aerial flight, but no real success as traveler of the air is found until we reach the group of insects, where wings—true aerial organs of locomotion—become a conspicuous characteristic of the group. How well they have succeeded is testified by the fact that such locomotion has been in vogue with them since early paleozoic time, and, considering their size, the speed and endurance exhibited in air is equaled by no other kind of animal.

The flying-fish, driven from its native element by pursuing foe to temporary elevation in the air, is a strange abortive attempt to reach this goal, but it has taken too direct a course ever to succeed. It should have first become an air-breathing land animal before attempting the soaring act. The frogs and lizards with expanded feet for floating on the air are poor apologies for flying animals, but given time might reach that goal were not the field so fully occupied by more dominant forms. The ancient flying reptiles, known only by their fossils, reached a high degree of efficiency, if we may judge by the expanse of wing they show. In their time they were doubtless the dominant types of the air, but they left no legacy to later forms, for the wings of modern groups are formed on different plans and must have been developed *de novo* or regardless of the reptilian type.

So now we reach the birds—the truest, most perfect of aerial forms, the animals which, with natural organs, have come nearest to annihilating time and space—whose skill in traversing the trackless regions of aerial waste has been the constant envy of man, from early time down to Darius Green, Maxim and Langley and a host of modern inventors. 'O had I wings' in various refrains has been the lament of man till we may expect ere long that the want will be practically supplied. Some birds indeed do not seem to appreciate this gift and have sacrificed these organs to adapt themselves to water or to a speedy gait on land, but flight is the dominant mode of locomotion for the group. Some of the mammals, aside from man, have attempted to follow the lead of the birds and the bats have succeeded so well that they are practically cut off from all other modes of locomotion, while flying phalangers, flying squirrels, and others attest the effort in various groups to adopt this rapid though hazardous kind of locomotion.

Special Adaptations.

Along such general lines, such open roads as these, animal life has progressed, and without such limitations as to prevent further progress or adaptations to new conditions. But I wish now particularly to call attention to certain adaptations that result in a definite limitation of the animal, a fitness to special conditions and a fitness so complete that existence under other conditions is impossible, or to put it still more broadly, a return adaptation is probably impossible. Such lines of adaptation may be looked upon as by-paths or blind alleys sought out by certain forms as presenting easier conditions for existence or into which feeble species may be crowded by the force of stronger ones. Places where certain shifts provide adequate chance for survival, albeit on a lowly plane.

Such by-paths are innumerable—almost as the nooks and crannies into which organisms may crowd—and to catalogue them would be to survey a large field of zoology. They are especially interesting and instructive as showing in most emphatic manner the factors that have been operative in modifying structure and attesting the general fact of evolution. The animals that are sedentary, domestic, subterranean, parasitic; the inhabitants of caves, deserts, manufactured products, oil, vinegar, hot springs, snow and ice, on islands, under bark, in deep sea, are illustrations of such erratic departures from normal habits. While we can review but few, these few may serve to illustrate the principles involved and some may be grouped under general heads.

Perhaps the least departure from normal, free-living conditions is presented by those animals which assume a sedentary habit. This may range all the way from a temporary anchorage in mud or on a rock to permanent attachment with most fundamental changes in form and structure of the organism. It is exhibited in some degree by almost every group of animals, and were it not that its tendency is toward limitation and restriction of powers we might look upon it as one of the main avenues of development. For minute forms the attached bell animalcules, stentors, etc., are good examples, and in sponges we find this habit of fixture a constant feature and associated with marked inferiority in symmetry and activity. Hydroids, and especially corals, show it strongly developed, though the former often present free living stages alternately with the fixed. Some worms and mollusks have assumed the rôle and it was the rule with echinoderms in early time, though modern forms have largely broken away from it, not, however, until their whole symmetry had been impressed by the results of their position. The barnacles among crustacea have gone farthest in this direction, and their symmetry and structure have been so strongly influenced that it is not strange that earlier naturalists failed to suspect

their true relationship. Mollusks, like the oyster, have also been much modified by fixation, and among insects the remarkable scale insects present extreme results in this direction. It is not mere chance that the oyster and the oyster shell bark louse have similar shape. They have both been modified, quite independently and in different locations, by the same controlling factors working on a sedentary organism. Many other insects in one stage or another illustrate this phase, but space forbids their mention.

Tunicates have traveled this road and thereby lost the rich inheritance that was theirs had they cultivated their backbone instead of allowing it to pass into 'innocuous desuetude.' Even among vertebrates we see some tendency to adopt the tied-up plan, for among the fishes the lampreys attach themselves to other fishes, the remours to the belly of the shark, the sea horse temporarily fastens to branches of coral by wrapping around them his flexible tail, the flounder rests almost fixedly at certain points, but throughout the group there is practically no permanent fixity with the degeneration it entails. It will be seen by those familiar with the forms cited that the mere fact of an animal having become habitually attached in a certain place and having lost its power of free movement has greatly affected its structure and future possibilities. It has bettered its chances for survival, but it has sacrificed all hope of progressive development. I believe it is quite safe to say that no high type of animal life can be referred in its origin to a sedentary ancestry.

Another frequent by-path is that of parasitism, and, indeed, so common is this mode of life, so prevalent in some degree or other among animals of almost every branch, that it would appear to be one of the easiest roads to travel. But this road leads inevitably to restriction of freedom and limitation of sphere—often to degeneration of some portion of the organism. Its ultimate end is extreme limitation and probable extinction. Protozoans, coelenterates, worms in great numbers, crustaceans, insects, mollusks and even some remarkable vertebrates have followed this road, and in every case where the habit has gone to any great extent it would seem impossible for them to retrace the route. Wherever the parasite has become limited to a single host or to alternate hosts, destruction of the host form means death to the parasite, and extinction of the host would mean extinction of the parasite. Loss of wings in formerly winged forms, loss of eyes and other organs of sense, loss of nervous system, loss of motion, loss of digestive organ even, in extreme cases, are the penalty they pay. 'Sans eyes, sans ears, sans nose, sans mouth, sans everything,' but actual necessities of existence and reproduction.

At first thought it may not seem so strange that wastes of desert land should present no small degree of living activity, but if we notice

the conditions more carefully, we shall see that we must provide not only for the survival of the individual, but for succeeding generations of individuals, and, when we take into account the special adaptations that become necessary to permit of the development of eggs and the early stages of the different forms, it will be seen that the problem becomes much more difficult. As already hinted we can scarcely conceive of life originating under such unfavorable conditions, but must think of it as having gradually extended its range from adjacent, more habitable regions. We can see, too, that the special adaptation in this direction distinctly unfits the animal for a return to a more humid condition and, if its desert conditions were withdrawn, the probability is that it would succumb to the pressure of more active forms of life. In fact we may gather that desert forms have reached such situations as an effort to escape from the more rigid contest in regions more densely habited.

Many tribes of men have thus pushed out into arid territory, adjusting themselves as well as possible to the conditions, but always with a struggle against these special conditions that can be scarcely less severe than the struggle against stronger individuals or races that have attempted their subjugation or extermination.

Aquatic forms we may expect to be absent and still some such aquatic forms as may develop very rapidly in temporary pools of water and are otherwise adapted to long periods of desiccation have solved this problem. Birds and insects may by their ready locomotion easily take to temporary quarters under desert conditions, and some of them become fixed inhabitants, but usually with some degree of subterranean habit to protect themselves from the severity of the sun's rays, thus burrowing owls and many subterranean or nocturnal insects are characteristic of desert life. Burrowing squirrels, prairie dogs, snakes, lizards, etc., all follow the same line.

Another distinct line of adaptation is shown in the animal life inhabiting caves, a fauna so characteristic and so strikingly similar in different parts of the earth, though common origin is out of the question. Such life might be looked upon as an extreme of subterranean forms living near the surface of the ground, but there are different conditions to be met, and the results are in many cases widely different. Loss of eyes would seem to be the most frequent and, indeed, almost the first effect of such adaptation, and this modification alone would practically preclude such animals from ever attaining a successful hold upon ordinary conditions. Return to conditions of light would expose them mercilessly to the attacks of animals with ordinary organs of vision. Blind fishes, blind insects, blind crustaceans, all attest to the controlling influence of environment, and whether the animals found in these locations have come there by choice to secure cer-

tain favorable attractive conditions, to escape more dominant forms outside, or simply by chance, from being carried in streams of water into these subterranean cavities, the result has been the same for all, and their return to the struggle carried on by their ancestors out of the question. They are distinct species modified and adapted to this particular environment where survival is possible, but opportunity for progressive evolution too limited to permit of advance.

Along the path of protective devices, mimicry, adaptive coloration, form and habit have traveled a host of different forms—flies that look like bumblebees and thereby gain entrance to their nests to provide extra food for their larvæ; butterflies that look like leaves of trees; leaf insects (phasmids) so like the leaves they live upon as to be invisible to foes; bugs that look like ants; scale insects that look like excrescences on the bark of the trees they infest; edible species that have taken form and color of inedible species; toads that look like lumps of earth; frogs that look like green scum or leaf at water side; snakes and lizards in great numbers that resemble the soil on which they live; birds that so closely imitate the colors of earth, foliage or irregularities of bark as to escape observation—in fact, an unending train in varying degrees, furnishing a most fascinating field for study.

Among aquatic animals we have fishes that hug close to the bottom and acquire color and pattern which admirably protect them, and the flounder has even gone to such an extreme in this direction as to have one of its eyes transferred from its normal position to the opposite side of the head. Skates and rays have the same flattening, but retain their normal position. Other fishes resemble rocks and so perfectly as to be practically invisible. Others, like sea horses, resemble parts of sea weed, streaming in the currents of water or branches of coral to which they cling. Mollusks and crustaceans adopt this plan to make themselves inconspicuous, and the different devices shown would fill a volume. Perhaps no stranger combination is presented than in the little crab which makes its home in a mollusk shell, but not content with this protection conspires with a sea anemone to take root upon its house top and add the variety of its structure to the deception. A queer sight these anemones, nodding here and there as borne by a hidden crab.

Most animals aside from man have been content to let electricity alone, and we are inclined to think the use of this magical force in nature of very recent origin. However, some of the aquatic animals, at least, and these forms that must have had their origin in the long, long ago of geological time, have brought to their use this elusive force and present in the structure of their organs for the generation of electricity some quite remarkable parallels to the electric apparatus of human invention. In such lines we have the torpedo, a broad, flat,

peculiarly spotted form common to the Mediterranean and adjacent seas capable of liberating a charge that will shock man and must be destructive to hosts of smaller animals, upon which it is doubtless used as a means of offense and defense; in the electric siluroid of Africa, which in different structure possesses the same power in greater force, and still more pronouncedly in the electric eel of South America, the shock from which is sufficient to paralyze a horse. What strange combination of circumstances has conspired to develop such a power in these animals? Evidently some condition common to their several environments, as it must have originated independently in each of the examples cited. The difference in position and structure, though all are modified from muscular tissue, is such that no common origin can be assigned to the structure in the different forms.

In the adaptations to deep sea life we have one of the greatest extremes and, since we have here one of the most remarkable series of animals and moreover one which until recent years has been unknown to science, it will not be amiss to give it more than passing notice. In the greater depths of the ocean we have conditions rivaling those of caves in the absolute exclusion of light, but very different in the medium and in the enormous pressures to which the animals are here subjected—pressures so great that when deep sea animals are brought to the surface there is an expansion of all the soft parts, an extrusion of the eyes, stomach, etc., producing most monstrous looking forms. But the passage from moderate depths to deeper and deeper points and, finally, to the abysses of mid-ocean are gradual, and we can conceive a gradual pushing off to deeper and deeper points till enormous depths are reached. Even yet, however, it is believed that the deepest reaches are uninhabited and uninhabitable, the lowest points from which life forms have been secured being far above the extreme depths that are known.

The wonderful discoveries of the 'Challenger,' 'Albatross,' 'Blake' and other deep-sea explorations, adding a new chapter in science and whole new groups of animals hitherto unsuspected, are yet so fresh in the minds of those interested in such matters that they may well serve my purpose in illustrating those special adaptations reached by animals that have pushed into apparently inhospitable regions. The passage in this case has, however, been slow. We need assume no sudden change of physical conditions tending to produce modifications of structure, but practically unaltered physical conditions and a simply crowded condition of life forms in regions already occupied, as the main factor in pushing into this *hinterland* of habitable zones. Here as in caves we should expect the loss of light to result in the loss of eyes, but this is not always the case, for in some of these grotesque denizens of the deep instead of the loss of eyes we find the development of marvelous

phosphorescent organs which serve as a lamp to light the pathway of these strange creatures in their strange surroundings. Such adaptations can hardly be conceived as possible, save with the very gradual shifting from lighter to darker regions through the lapse of thousands and thousands of years.

In modern times, since man's domination began, another factor has appeared, and its influence in modifying animal forms and structure has been one of the most potent and striking for such as have fallen within its scope. While man's effort has been largely to exterminate the lower forms of life, especially those inimical to his interest, he has utilized others for his service, and in the process of domestication we may see compressed into brief time such changes as under natural conditions would have occupied untold years, if, indeed, they would ever have been possible, since many of these changes unfit the forms for survival under natural conditions. So potent this factor that the immortal Darwin used its results as furnishing some of the most conclusive testimony for the theory of natural selection, believing that what could be accomplished in brief time by artificial, or human, selection could be accomplished in greater time by natural selection.

To see the power of this factor we may compare the various breeds of cattle and refer all to the primitive form from which we have absolute historic evidence that they were derived. The breeds of horses are equally striking, as the immense draft horse, the Shetland pony, the thoroughbred racer and the Arabian with hosts of special strains will attest. So, too, with dogs, cats and fowls. The pigeon which furnished Darwin with so much evidence since the native rock pigeon, the extreme breeds of fantails, carriers, etc., can be seen side by side and their relationship unquestionably fixed. Now I wish particularly to call attention to the fact that many of these domesticated forms, as a result of their domestication, have been unfitted for life in other spheres, and if dropped from the fostering care of man would almost certainly suffer rapid extermination, those surviving being the ones that had been least affected by the process of domestication. A modern hog would stand a poor show, but the southern razor-back doubtless would survive, for a considerable period at least, without man's assistance. Here then is a by-path opened in very recent time and into which certain animals have been driven by man, seldom of their own choice, if ever, the confines of which have profoundly modified many and behind them the gates have been closed never to be opened again.

Pushing away from the congenial temperatures of equatorial and temperate regions, life ventures into the inhospitable frozen zones of the polar regions, and by adaptation to such clime invades the most forbidding sphere. Earth's 'warm embrace' is here a 'cold reception,' but hosts of birds, mammals, fishes and insects have become established

and would doubtless suffer extinction in other apparently more congenial regions. Such is evidenced by the fact that certain formerly arctic forms have secured survival or at least a postponement of extinction in low latitudes by ascending mountain peaks or ranges, the assumption being that such forms were pushed southward during glacial periods and that some instead of retreating with the glacier took advantage of high latitudes to secure similar conditions. But while adaptations to the rigorous conditions of high latitudes must mean great hardihood, it also means small chance for progress in other lines and we do not look for progressive development in such situations. The Esquimaux and Laps will hardly produce Gladstones, Blaines, Leo XIII.'s, Bismarcks or Grants. But while extreme cold is unfavorable to life, extreme heat is equally so, and the limits in this direction are perhaps even more strictly marked.

Nevertheless, we find aquatic animals that have adapted themselves to life in hot springs, numerous forms living in water of 100° F., while some forms occurring in hot springs of the famous Yellowstone region exist in temperatures which, except to those especially adapted, would be destructive. On the barren slopes and crests of mountains the conditions for supporting life are also very severe, especially where altitudes are such as to leave all forest growth below or to reach into the regions of perpetual snow and ice. Still such inhospitable quarters are sought out by many animals and various small mammals, many birds and insects may be found keeping up the struggle against the boundaries to life's outskirts.

Another most interesting phase of adaptation is to be noted in the community life exhibited by ants, bees, termites and some other groups. The community habit has resulted in the development of various castes, some of which have assumed the full duty of reproduction, others fitted only for the labors or defense of the colony. In some cases slavery follows this division of labor, the members of other colonies or other species being kept in captivity and utilized in carrying on the duties of the colony except of course that of reproduction. In some species we are assured this has gone so far and the slave-making species has become so dependent on the slaves that without them they will die of starvation. Community life then is an extreme specialization offering many advantages, but at the same time entailing certain limitations, cutting off the individual from any possibility of independent existence and the colony from survival, except under the conditions that have been established with the community life. Return to primitive isolated life is manifestly impossible.

These constitute some of the most striking by-paths into which life forms have been diverted either from choice or necessity, but barely a

hint of the multitudinous minor lines of adaptation, the following of which results in limitation.

Such forms of insects, crustaceans, worms, etc., as have taken to living under bark and wood and become so flattened as conveniently to slip between the wood and bark in crevices scarcely permitting the passage of a sheet of paper—mollusks which bore into piles or some into solid rock—barnacles that fasten to ships and thus reach all climes—insects that thrive in such unnatural food material as tobacco, insect powder; or larvæ that live in brine vats, wine vats, or, perhaps most extreme, in crude petroleum. Vinegar eels in vinegar and hosts of forms that subsist upon hams, bacon, flour, meal and other prepared foods, boots, shoes and other leather goods, and furs show the readiness with which new habits are acquired. But these habits are not so easily broken, and it is doubtful if the cheese maggot, having taken up its particular dietary furnished by man, could return to the food of its ancestors before cheeses were made.

I have spoken in places of the choice of animals for a particular sphere as if this were a conscious element, and I do not care to dispute those who maintain some such element as operative in the mutations of animal life. But, conscious or unconscious, it appears to me that the animal, even in a lowly sphere, has the power to choose in some degree or other the direction of its activity, to put itself in certain environments, and while not selecting certain changes of structure by the mere fact of selecting such environment, submits itself to inevitable changes which that environment must perforce produce. Thus, an animal may not elect to become flattened in body, but selecting narrow quarters in which flattening is necessary or advantageous this change is sure to follow.

The ancestors of snakes may not have determined upon eliminating legs from their anatomy, but by choice of habitat where legs were in the way these organs were gradually reduced and lost. But by no process of electing locations where legs are helpful can we expect the animal to restore the organ thus sacrificed. The fly that mimics a bee may never in its ancestral line have started out to make itself resemble a bee, but it may have chosen such relation to bee life that a similarity became distinctly advantageous or even necessary, and then natural selection could clearly come into operation to produce the mimicry. The ancestral whale had no glimmer of thought of launching into marine life, to trade his feet for paddles and flukes, when he first by virtue of some advantage found entrance to water desirable, but once the way was entered, selection and environment conspired to carry his descendants further and further along a path which knows no backward steps.

What fearful consequences attend these unconscious selections! Shall it be persistence or progress, mere survival or advancement—the

starting on a downward path to extinction or an upward path to domination, a wanton sacrifice of rich legacies of structure or improvement of such as may be possessed?

While adaptations and progressive modifications have been the rule, there are a few striking exceptions, and we can not assert that preservation of a particular plane of development is impossible. Picture the little lamp shell, *Lingula,* living on unaltered from age to age, its fossils being found away back in the earliest Paleozoic time and in subsequent ages up to the present day—so much for staying at home and attending strictly to its own business. True no change—no progress—but as an example of the staying qualities nothing can be more striking.

Concluding, then, we may look in wide view at life as originating in most favorable conditions of moisture and temperature; as pushing out to occupy all favorable environments, and then, from the congestion of life in such places, as pushing out to extremes in various directions and, ultimately, by a process inherent in life itself, constantly but unconsciously striving to occupy every available niche having the remotest possible opportunities for the support of organic beings. The animal choosing its environment and the environment reacting to modify the structure of the animal.

But this pushing has been along different lines and some of these involve no such radical change of form or habit as to restrict the animal to a special environment. In such broad highways progressive evolution is still possible, and we may expect future modification, advancement, adaptation, the height to which advancement is possible depending on how fully the animal may preserve its general varied structure while reaching such perfection of organs as to enable it to dominate the forms with which it must compete for mastery.

Where the road narrows and the animal in traversing it is obliged to sacrifice some portion of its structure and to adopt some restriction of habit the result is a limitation which must ultimately mean a bar to all progressive evolution in the acceptance of a particular limited sphere within which it may survive, but to leave which means extinction. Adaptation to sedentary life, parasitism, desert, cave, deep sea, polar frigidity or extreme heat is to shut the door of progress and give over to mere survival.

We may be tempted to moralize a little, for a moment's thought assures us that man himself is, like other animals, subject to these inevitable laws, and that retrogression, degeneration, decay and extermination are as possible to him or to certain of his races as to any other form of life, but this subject widens into the great new field of sociology—one of the latest, richest and most important of the branches of biology.

THE CORRELATION BETWEEN MENTAL AND MORAL QUALITIES.

By FREDERICK ADAMS WOODS, M.D.,
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

IN the present article I propose to present for the first time, so far as I know, some figures proving a perfect correlation between mental and moral qualities. In addition, I have some data showing, not the birth rate, but what is more to the point, the number of children who have reached *adult* age, born to ten different groups of parents, arranged according to their moral qualities. Both series of facts taken together give us an insight into the progress of the purely intellectual faculties. They show how the *mental* level in each generation may be raised by no other force than natural selection.

The complete acceptance of the theory of the 'survival of the fittest' as an explanation of evolution has had for one of its greatest bugbears the disbelief that such a force could of itself be sufficient to explain improvement in the higher human traits. In the lower forms of animal life the advantages of intelligence in the struggle for existence are evident. Cunning and strength mean better sustenance or surer escape from natural enemies. But how can such brute forces as these be of determining significance among individuals of the human species, especially during the latter ages in which man has risen above barbarism? That man has evolved is admitted, that he will continue on the upward road is generally believed, but how is an unsolved problem.

For those who believe in the inheritance of acquired characteristics, the accumulated effects of education and superior outward advantages are the forces on which the present has been built and on which the future is to rely. For those who doubt or deny the old Lamarckian principles, and we believe an increasing number of naturalists belong to this school, no such easy explanation is at hand. Some writers consider that acquired characteristics are probably not directly inherited through the physiology of the hereditary mechanism, but that the accumulated culture of each generation creates a new environment which in each generation becomes the bequest handed on to the next. In this way institutions, scientific improvement and traditions go on from century to century in their work of building up the race. It is difficult to see how men really and essentially improved or superior in natural endowments could ever be produced through the working of such a process, even in an aeon of time. And, indeed, it is denied that

human nature has at heart changed or ever will change. To the minds of some, civilization is but a gloss and a veneer, politeness and kindliness are maintained while everything runs smoothly, but let danger or necessity arise, and they say man is again thrown back on his brute passions.

For a discussion of the question, 'Is the mean standard of faculty rising?' and the citations from various authors who consider that it is not (Buckle, Bellamy, Ritchie, Gladstone, Benjamin Kidd, *et al.*), see Lloyd Morgan, 'Habit and Instinct,' where he himself states in his closing paragraph: "Natural selection becomes more and more subordinate in the social evolution of civilized mankind; and it would seem probable with this waning of the influence of natural selection there has been a diminution also of human faculty." Alfred Russel Wallace writes:* "In one of my latest conversations with Darwin he expressed himself very gloomily on the future of humanity, on the ground that in our modern civilization natural selection had no play, and the fittest did not survive." Wallace himself insists that there are forces to be counted on for the amelioration of the race, one of which is the process of *elimination* 'by which vice, violence and recklessness so often bring about the early destruction of those addicted to them.' But it is much more difficult at first sight to see how purely intellectual qualities are to be enhanced through any process of natural selection going on at the present day. Nevertheless, if a mental and a moral correlation can be shown to be a reality the difficulty is overcome.

The following figures, which prove that the morally superior are also the more endowed mentally, were drawn from records of the characteristics of European royalty. They include the entire number who formed the basis of a study of heredity which appeared in The Popular Science Monthly, August, 1902, to April, 1903. These were arranged to the best of the writer's ability, and in consultation with John Fiske and other historians, in ten grades for intellect and ten grades for morality. The latter term is used in its widest meaning and under this head are included all the qualities which may count as virtues. Amiability and kindliness are included, so that only those who have received praise for many good qualities can appear in the higher grades. The highest grade (10) is for those only who have been known as altruists, or reformers, or have devoted their lives to charity or other noble aims for the welfare of their country.

It has been the aim of the writer to take only the opinions of others, following the biographical dictionaries and standard histories as far as possible. If a personal equation may have unconsciously influenced the grading, it can have no possible effect on the results of the present article, because the grading was made with a view to the study of in-

* 'Studies Scientific and Social,' London, 1900, Vol. 1, p. 509.

heritance, without the least idea of carrying forward the present research. It had always been a matter of grave doubt in my own mind whether the exceptionally gifted of earth were better or worse than the ordinary run of mankind. Examples like Napoleon, Bacon, Byron and Catherine II. of Russia come to mind, and then we all have a feeling that the very good are perhaps a little simple-minded, and besides, according to tradition, they 'die young.' This pessimistic view of things is, however, not borne out by the facts.

On looking over the number of individuals in each grade one sees that nearly a half of all concerned fall in the two middle grades (5) and (6). This exemplifies what is known as 'the law of deviation from an average,' and means that when a large number of measurements are taken of any biological characteristic and graded in a numerical series, they will fall so that proportionally more lie in the grades approaching the mean and less and less as the measurements show extreme variation. On this view, then, in any homogeneous group of persons, fools are as rare as geniuses, and may differ much from the mean; but the great mass of humanity are such that in any given characteristic, one is much like another. The social scale is not to be conceived of as a pyramid in which the favored few are represented at the apex, and the masses below, more and more numerous as we descend the scale; but rather as a figure like a Rugby football with the masses occupying the medium zone. Actual paupers are as rare as the very rich. In the tables below we see the frequency in each of the ten grades for moral qualities, the males and females having been studied separately.

FEMALES.

Grades.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
Frequency.	7	8	18	24	60	42	28	23	16	6	= 232

MALES.

Grades.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
Frequency.	9	19	36	49	73	51	47	44	25	12	= 365

Space will not permit printing an entire list of 597 names or giving bibliographical references. Such details will be included in a work on the general subject of heredity in royalty which I hope will appear shortly. The three upper and three lower grades are, however, given below, and since the results of study of the extreme ends determine largely the conclusion obtained, the majority who lie close to mediocrity may just as well be given less attention.

It is, of course, difficult, indeed impossible, for any one to arrange people according to their reputed virtues in a perfectly satisfactory manner. It is, however, not as difficult as it might at first sight seem, especially if one remembers that by far the majority are to be in the

mediocre grades and the presence of some little vice or a reasonable array of good qualities are not to place a man in an extreme grade in either direction. In the case of the women the standard proved to be such that it was necessary, in order to make things balance, to place all excellent, quiet and negative characters in a grade as low as (5) and reserve the upper grades for those only who have had a special reputation for devoting their time to some form of altruism. Those who are familiar with history and court memoires may see how far the grading suits their particular approval, and most who read the list carefully will doubtless object to characters here and there; but I am sure that much of this will be found due to some personal bias, and an acquaintance with all the characters would result in a scheme not very different from the present. It is to be remembered that they are not arranged by the writer from a vague idea of their worth drawn from reading accounts of their lives, but are graded purely on a basis of the adjectives used in describing their traits by the best authorities, several different sources of information having been used for verification. In any case errors would be likely to balance.

The three lowest grades have been reserved for the distinctly vicious, those described as debauched, depraved, licentious, dissipated, cruel or extremely unprincipled. In the three upper grades we find such descriptions as 'Adored by the people as a saint,'* 'Gave herself up entirely to works of piety and charity,'† 'Heroic virtues and rare abnegations,'‡ 'By his well-known devotion to the best interests of the country he secured the confidence and esteem of all classes,'§ 'Respect and veneration which the Russians entertained for his character.'‖

In the list following, the persons within each grade are given in the alphabetical order of the country or family name, which is followed by the christian name. When the family name is omitted, it is the same as the preceding. The numbers in brackets which stand before the names are the intellectual grades in each case, and those following, without brackets, refer to the total number of children who reached adult years.

Thus (10) Anhalt, Catherine II., Empress of Russia, 1: means that she was by birth of the House of Anhalt, that she stands in grade (1) for virtues, grade (10) for mental qualities and that she left one adult child. The averages at the bottom are indicated in the same way. Illegitimate children are also included in the number.

In regard to the variability of the two sexes one sees that the con-

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* Christine, dau. of Victor Emanuel I. of Savoy, and first wife of Ferdinand of Sicily.

† Anne, de Mancini, wife of Amand, Prince of Conty.

‡ Pedro II. of Portugal and Brazil, 1825–1891.

§ Leopold I. of Belgium.

‖ Feodor I. Romanhof.

clusion to be drawn is that the males are the more variable. The females fall less often in the extreme grades, which agrees with the generally accepted view. Karl Pearson has, however, doubted the greater variability of the male.*

FEMALES.

Grade (1).

(10) Anhalt, Catherine II., Empress of Russia, 1; (8) Orleans, Elizabeth, dau. Philip (Regent), 0; (5) Marie, dau. Philip (Regent), 0; (3) Russia, Elizabeth, dau. Peter the Great, 0; (1) Saxony, Anne, second wife Wm. the Silent, 2; (6) Spain, Marie Louisa, wife Charles IV., 6; (4) Queen Urraca, 1; ...... (5.28) Average 1.43.

Grade (2).

(5) Brunswick, Caroline, wife George IV. of Eng., 0; (5) Portugal, Isabella, dau. Don John, married John II. Castile, 1; (5) Mary, dau. Alfonso IV., 1; (3) Russia, Anne, 1694–1740, 0; (5) Savoy, Joanna, dau. Charles Amadeus, 1; (6) Spain, Carlotta, d. 1830, dau. Charles IV., 6; (5) Isabella II., b. 1830, 6; (6) Maria Christina, married Ferdinand VII., 2; ...... (5.00) Average 2.13.

Grade (3).

(7) Austria, Caroline, Queen of Naples, d. 1814, 7; (5) Maria Louisa, married Napoleon; (5) Bourbon, Elizabeth, dau. Louis XV., 3; (6) Brunswick, Caroline, married George IV. of England, 1; (7) Elizabeth Christine, married Frederick William II. of Prussia, 1; (8) Juliana, Queen of Denmark, 1; (4) Condé, Henrietta, dau. Louis III., 0; (5) Louise, dau. Louis III., 2; (4) Marie, dau. Louis III., 0; (5) Conty, Louise, dau. Amand, 2; (5) Medici, Marie, wife Henry IV. of France, 2; (5) Orleans, Charlotte, dau. Philip (Regent), 5; (5) Portugal, Anne, dau. John VI.; (3) Russia, Catherine, wife Peter the Great, 2; (8) Spain, Joan Henriquez, wife John II. of Aragon, 1; (6) Louise Carlotta, b. 1804, dau. Francis of the Two Cicilies, 7; (8) Theresa, dau. Alfonso I. Castile, 3; (5) Sweden, Cecilia, dau. Gustavus Wasa, 3, ... (5.66) Average 2.50.

Grade (8).

(5) Bourbon, Louise de Blois, dau. Louis XIV., 7; (5) Louise, dau. Duke de Penthièvere, 4; (10) Margaret of Navarre, grandmother of Henry IV. of France, 1; (5) Brandenburg, Anne, Queen of Denmark, 2; (9) Brunswick, Anne, dau. Saxe-Weimar (patron of Goethe, etc.), 2; (6) Elizabeth, married Charles VI. of Austria, 2; (7) Coligny, Louise, wife William the Silent, 1; (7) Condé, Louise Adelaide, 0; (4) Denmark, Caroline, dau. Frederick VI.; (4) Hanover, Caroline Elizabeth, dau. George II., 0; (6) Montmorency, Charlotte, married Condé, 3; (5) Plantagenet, Philippa, Queen of Portugal, 6; (5) Portugal, Elenor, Queen of John II., 1; (4) Marie Isabelle, dau. of John VI., 0; (6) Matilda, dau. Sancho I., 0; (9) Prussia, Amelia, sister of Frederick the Great, 0; (7) Russia, Anne, dau. Peter the Great, 0; (6) Savoy, Maria, Queen of Philip V. of Spain, 2; (8) Saxe-Meiningen, Louise Dorothea, 'the German Minerva,' 3; (8) Spain, Isabella, dau. Philip II., 0; (8) Marie, wife of Sancho IV., 6; (5) Spain, Marie Amelia, wife Louis Philippe, King of the French, 8; (7) Sancha, Queen of Ferdinand I., 5; ...... (6.35) Average 2.41.

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* Conf. 'Variation in Man and Woman,' by Havelock Ellis, POPULAR SCIENCE MONTHLY, January, 1903, Vol. LXII., No. 3.

Grade (9).

(5) Austria, Elizabeth, dau. Maximilian II., 0; (5) Margaret, dau. Maximilian II., 0; (9) Maria Theresa (the great queen), 10; (9) Bourbon, Jeanne d'Albret, dau. Henry of Navarre, 2; (8) Brandenburg, Caroline, Queen of George II. of England, 7; (6) Brunswick, Charlotte, Czarina of Russia, 2; (4) Elizabeth, wife Frederick the Great, 0; (6) Denmark, Charlotte Amelia, dau. Frederick IV., 0; (9) Hanau, Amalie Landgräfin von Hessen, 4; (8) Hanover, Sophia Charlotte, Queen of Frederick I. of Prussia, 1; (5) Hesse, Charlotte Amelia, Queen of Christian V. of Denmark, 3; (5) Mecklenburg, Charlotte, Queen of George III. of England, 13; (8) Prussia, Charlotte, sister Frederick the Great and Duchess of Brunswick, 8; (8) Russia, Natalia, dau. of Alexy, 0; (8) Spain, Berengaria (famous queen), 5; (7) Stolberg, Juliana, mother William the Silent, 11; ...... (6.88) Average 4.13.

Grade (10).

(6) Hanover, Queen Victoria, 8; (5) Mancini, Anne, wife of Amand Prince of Conty, 2; (10) Prussia, Louisa Ulrica, Queen of Sweden and sister Frederick the Great, 4; (5) Savoy, Christine, dau. Victor Emanuel I., 1; (10) Spain, Isabella of Castile, 4; (8) Saint Elizabeth, Queen of Diniz I. of Portugal, 2; ...... (7.33) Average 3.50.

MALES.

Grade (1).

(1) Brunswick, Ivan, s. Anton Ulric, 0; (3) Condé, Charles de Charlois, s. Louis III., 0; (2) Denmark, Christian VII., 2; (5) Farnese, Ranuccio, 1569–1622, 6; (1) Portugal, Alfonso VI., 0; (2) Spain, Don Carlos, s. Philip II., 0; (6) Peter the Cruel, 6; (1) Philip, s. Charles III., 0; (2) Russia, Alexy, s. Peter the Great, 1; ...... (2.56) Average 1.88.

Grade (2).

(2) Bourbon, Gaston d'Orleans, s. of Henry IV., 3; (3) Louis XV., King of France, 6; (2) Hanover, Frederick Henry, b. of George III., 0; (4) George IV., King of Great Britian, 1; (4) Maillé, Urbain, 1597–1650, 2; (8) Medici, Cosimo the Great, 5; (4) Francesco, 1541–1587, 4; (2) Portugal, Cardinal Henrique, s. Emanuel I., 0; (4) Don Miguel, s. John VI., 7; (8) Russia, Constantine, s. Paul I., 0; (3) Paul I., s. Catherine II., 9; (2) Spain, Don Balthazar, s. Philip IV., 0; (1) Charles II., 0; (2) Ferdinand, Duke of Parma, 1751–1802, 4; (5) Ferdinand II. of the Two Sicilies, 7; (3) Francis I. of the Two Sicilies, 12; (3) Henry IV. of Castile, 0; (5) Philip II., 4; (5) Philip IV., 4; ...... (3.68) Average 3.58.

Grade (3).

(7) Austria, Francis IV., Duke of Modena, 4; (6) Francis V., Duke of Modena, 0; (5) Rudolph II., Emperor, 0; (2) Bourbon, Charles Duke of Berry, s. Louis the Dauphin, 0; (3) Louis XIII., King of France, 2; (4) Brandenburg, Charles William, d. 1712, 1; (7) Condé, Henry Jules, s. the Great Condé, 4; (7) Hanover, Ernst August, father of George I., 6; (3) Frederick Duke of York, s. George III., 0; (3) Frederick Prince of Wales, s. George II., 0; (3) George II., King of Great Britain, 7; (6) William Augustus, s. of George II., 0; (5) Mecklenburg, Charles Leopold, married Empress of Russia, 1; (4) Orleans, Louis Philippe (Egalité), 4; (8) Philip (Regent), 9; (7) Alfonso III., 6; (7) Alfonso IV. the Brave, 2; (3) Ferdinand, s. Peter the Rigorous, 2; (3) John III., 2; (7) Prussia, Frederick William I., 10; (9) Russia,

Peter the Great, 3; (2) Peter III., 1; (7) Saxony, Augustus I. the Strong. 2; (8) Spain, Charles V., Emperor of Austria, 5; (6) Ferdinand IV. of Castile, 2; (2) Ferdinand I. of the Two Sicilies, 7; (2) Ferdinand VII., King 1784–1833, 2; (2) Francis II. of the Two Sicilies, 1; (6) Henrique, 1823–1870, s. Francis de Paula, 5; (6) Henry II. (Transtamare), 1333–1379, 9; (8) James I. of Aragon (the Conqueror), 5; (3) John I. of Castile, 2; (7) John II. of Aragon, 4; (4) Louis, s. of Philip V. and Marie, 0; (7) Sancho IV. of Castile, 8; (6) Sweden, John III. 2; ...... (5.14) Average 3.44.

Grade (*8*).

(6) Anhalt, Charles William, 1652–1718, 2; (7) Austria, Maximilian II., 8; (6) Bourbon, Duke of Burgundy, grandson Louis XIV., 1; (5) Louis XVI., 1; (6) Louis Jean de Penthièvre, 2; (5) Brunswick, Anton Ulric, 1714–75, 5; (3) Charles, 1713–80, 8; (7) Ernest Ludwig, 1718–88, 0; (7) Ferdinand Albert I., 6; (7) Frederick August, 1740–1805, 0; (9) Coligny, Gaspard (the great admiral); (7) Condé, Louis Joseph, 2; (8) Denmark, Christian IV., 3; (5) Frederick VI., 2; (5) Farnese, Ranuccio II., 2; (4) Hanover, Duke of Kent, s. George III., 1; (7) Hesse, Philip the Magnanimous, 15; (5) Mecklenburg, Adolphus, 1738–94, 0; (5) Carl Ludwig, 1708–1752, 6; (8) Medici, Ferdinand I., 4; (4) Nassau, William IV., 2; (7) William II. (King), 4; (7) Frederick William, b. 1797, 2; (9) Orange, Maurice (celebrated general), 2; (7) William the Elder, father William the Silent, 12; (9) William III., King of Great Britain, 0; Orleans, Antoine Montpensier, brother Louis Philippe, 0; (6) Poland, Ladislaus, s. Casimier, 2; (7) Portugal, Edward I., 6; (8) Henry of Burgundy, d. 1114, 4; (10) John I. "the Great," 8; (8) John II., 2; (5) Joseph, s. John II., 4; (7) Louis, s. Emanuel, 1; (7) Sancho I., 8; (6) Sancho II., 0; (4) Savoy, Charles; (6) Saxe-Coburg, Frederick II., 9; (5) Saxe-Gotha, Frederick IV., 0; (7) Saxe-Meiningen, Anton Ulric, 5; (9) Saxony, Maurice (celebrated Elector), 1; (8) Spain, Ferdinand I., 5; (7) Sancho III., 1; ...... (6.57) Average 3.72.

Grade (*9*).

(9) Austria, Charles (commander against Napoleon), 6; (5) Ferdinand I., d. 1564, 13; (6) Ferdinand III., 6; (5) Leopold I., 6; (5) Brandenburg, Christian Frederick, d. 1806, 0; (7) Brunswick, Ferdinand, 1721–92 (General), 0; (8) William Adolphus, 1745–70 (author), 0; (8) Conty, Francis, b. 1664 (elected King of Poland), 3; (4) Hanover, Adolphus, s. George III., 3; (4) George III., 13; (7) Lorraine, Leopold, father Francis I. of Austria, 5; (6) Mecklenburg, Adolphus Frederick I., 12; (7) Montmorency, Henry II., 0; (8) Nassau, Frederick, b. 1774, 0; (6) Orange, John, Brother William the Silent, 16; (5) Portugal, Don Fernando, s. John I., 0; (9) Henry the Navigator, 0; (5) Prussia, Frederick William (late Emperor), 7; (9) Henry, brother Frederick the Great, 0; (7) Russia, Alexy, father of Peter the Great, 6; (7) Russia, Michael Feodorvitch, 1596–1645, 3; (5) Saxe-Coburg, Franz F. Anton, 7; (5) Saxe-Gotha, August, s. Frederick III., 0; (6) Ernest II., b. 1818, 0; (10) Sweden, Gustavus Wasa, d. 1559, 6; ...... (6.44) Average 4.48.

Grade (*10*).

(7) Coligony, Odet, 1515–1571, 0; (10) Orange, William the Silent, 13; (6) Portugal, Pedro II. of Brazil, 2; (7) Pedro V., king, born Saxe-Gotha, 6; (7) Russia, Feodor, the first Romanhof, 1550–1633, 1; Saxe-Coburg, Albert (consort of Victoria), 8; (6) Saxe-Gotha, August, d. 1772, 9; (7) Ernest the Pious, 9; (8) Ernest II. (the astronomer), 2; (5) Frederick III., d. 1772, 4;

(7) Leopold I. of Belgium, 3; (10) Sweden, Gustavus Adolphus, 2; ...... (7.3) Average 4.09.

Analyzing all the grades, we find that the higher grades for virtues possess a higher average of mental capacity and that this is almost perfect for both the male and female groups taken separately. An average of the two makes a curve that leaves practically nothing to be desired. There is every reason to believe that if the total were great enough the correlation would be perfect.

FEMALES.

Grades.	1	2	3	4	5	6	7	8	9	10
Correlation averages.	5.28	5.00	5.66	5.79	5.20	5.64	5.96	6.35	6.88	7.33

MALES.

Grades.	1	2	3	4	5	6	7	8	9	10
Correlation averages.	2.56	3.68	5.14	5.24	5.30	5.73	5.79	6.57	6.44	7.33

BOTH SEXES. (AVERAGED.)

Grades.	1	2	3	4	5	6	7	8	9	10
Correlation averages.	3.92	4.34	5.40	5.51	5.25	5.69	5.88	6.46	6.66	7.33

The average number of children who reached adult (21) years born to each grade is seen below to give figures representing a less smooth curve. This is probably due to an insufficiency in the total number, though I feel that this can not be dogmatically asserted.

FEMALES.

Grades.	1	2	3	4	5	6	7	8	9	10
Av. No. of adult children.	1.43	2.13	2.50	2.44	3.07	3.64	3.08	2.41	4.13	3.50

MALES.

Grades.	1	2	3	4	5	6	7	8	9	10
Av. No. of adult children.	1.88	3.58	3.44	2.41	3.58	3.46	3.04	3.72	4.48	4.09

BOTH SEXES. (AVERAGED.)

Grades.	1	2	3	4	5	6	7	8	9	10
Av. No. of adult children.	1.66	2.86	2.97	2.43	3.33	3.55	3.06	3.07	4.31	3.80

Such figures drawn from royalty, in regard to the fertility of different grades, can have, of course, but a slight bearing on the question of race suicide agitated at the present time. They do, however, show that, unhampered by restraint, as is fair to suppose has been the case

among royalty where large families are always desired, maximum fertility does on the whole run hand in hand with general superiority. Nearly all the figures which have been heretofore compiled upon the question deal only with the number born and not with the number reaching adult years and are consequently of absolutely no significance. It is a well-known biological principle that the lower the species the greater the number of offspring, but among the different members of any social scale, our foreign immigrants for instance, very likely it would be found on close inquiry that, *inter se,* the relatively superior are the ones who are parents of the greater number of children whom they are successful in bringing to mature years. There are many reasons, both medical and economic, why the children of the more vicious and depraved should die in the greater numbers. This, in the long run, must raise the moral average, and as mental qualities are correlated with the moral, the intellectual level must at the same time be raised.

Besides these problems touching upon natural selection there is another question upon which I wish to say a few words. I refer to the opinion so generally entertained regarding the psychological effect of the inheritance of great financial wealth. Wallace in his 'Studies Scientific and Social,' Vol. II., p. 519, in a paragraph headed 'Hereditary Wealth Bad for its Recipients,' writes:

> There is yet another consideration which leads to the same conclusion as to the evil of hereditary or unearned wealth—its injurious effects to those who receive it, and through them to the whole community. It is only the strongest and most evenly balanced natures that can pass unscathed through the ordeal of knowing that enormous wealth is to be theirs on the death of a parent or relative. The worst vices of our rotten civilization are fostered by this class of prodigals, surrounded by a crowd of gamblers and other parasites who assist in their debaucheries and seek every opportunity of obtaining a share of the plunder. This class of evils is too well known and comes too frequently and too prominently before the public to need dwelling upon here; but it serves to complete the proof of the evil effects of private inheritance, and to demonstrate in a practical way the need for the adoption of the just principle of equality of opportunity.

That instances of this sort do come too frequently before the public I do not deny. The vices of the aristocracy are always made the most of by the polychrome daily press, but if Mr. Wallace or any one else has any data to show that vices among the rich are proportionally more frequent than among people in general, I have never seen such a proof. It is an assertion entirely unwarranted by any facts. It is merely a popular fallacy which will probably be entirely abandoned as soon as sociology has properly collected data bearing on modern life. In the first place, it is unlikely on *à priori* grounds. Wealth, like most things in life, is essentially relative. To the young man who is to inherit a few thousand dollars, if he belongs in the middle classes, the

amount seems as much as the same number of millions to one whose friends all have as much. There are plenty of temptations within the reach of all classes of society and many demoralizing amusements come cheap. Besides, if this view of the evil effects of great wealth were true, royalty, who are among the richest of the world's favored few, should make a poor showing from the general standpoint of morality. Although we may think at first sight that this is the case, I have been able to show in some former articles in this magazine that the bad characters practically always come as close relations of others of the same stamp, and due to heredity with perhaps some influence from environment. They can not at any rate be explained on the ground of riches, as here all are rich. Furthermore, royalty does not make a bad showing when taken as a great group. From the intellectual side they are distinctly above the average and this six hundred contains more great names than probably any other collection of related people that could be gathered together, certainly more than the general run of Europeans. Even the greatest leaders among them were born in all cases to extremely high positions. An idea of their moral standard may best be gained by looking at their mean or (5) and (6) grades. Among the more modern and best known in these grades are the late Humbert, King of Italy, William I., Emperor of Germany, Frederick William IV. of Prussia, Louis Philippe and Francis Prince de Joinville, his son; doubtless men with faults, but at the same time men with certain decidedly praiseworthy traits and in most instances men who led active lives.

Wallace relies much on sexual selection to play an important part in the future, as a causative force in human evolution, and has written some good arguments to this effect. Royal matches, as is well known, are largely determined by reasons of state policy. Nevertheless, even here, in a class of society where any force of sexual selection must be relatively at its lowest, we see the largest number of children on the average belonging to the higher grades. There is also a pretty definite elimination of the worst.

Conclusions.—There is a very distinct correlation in royalty between mental and moral qualities. If this is true among them, there is no reason why it should not be true in every class of mankind. Among society in general it is easy to see how the vicious and depraved are more likely to be eliminated than the domestic and unselfish. Arguments, then, which prove that an improvement is going on in the general morality of any class or race must at the same time prove an increase in the standard of mental faculty. The probability is that forces of natural selection are at work, the value of which we know little of as yet, such that setting aside all influences of environment, whether we will or not, the natural quality of humanity must progress.

COOPERATION, COERCION, COMPETITION.

By Professor LINDLEY M. KEASBEY,

BRYN MAWR COLLEGE.

UNDER the title, 'Cooperation, Coercion, Competition,' I propose to consider the three characteristic systems of industrial organization. Having set forth in a few words what appear to me to be the determining factors of industrial organization, in the first part of my paper I shall endeavor to show that the three systems of association have succeeded each other historically in the order named, that in primitive times, before the appropriation of natural resources, the cooperative system prevailed, that during the proprietary period which followed, when natural resources were appropriated but before the institution of exchange, the cooperative system became subservient to the coercive system, and that with the rise of the commercial era resulting from the development of exchange, the coercive system was superseded by the competitive system. In the second part of my paper I intend to draw attention to certain tendencies which appear to me to point toward a reversal of the original order of evolution. Having shown why the competitive system was necessarily a transitional form, I shall indicate how it is now being superseded by the coercive system, and in conclusion I shall endeavor to demonstrate that the ultimate outcome must be the reestablishment of the original cooperative system.

My main proposition is that industrial organization is determined by two factors: first, by the character of the social surplus, and second, by the monopolization of the sources thereof. Instead of stopping to prove this proposition I shall proceed at once with the historical survey, hoping that in the course of such survey the requisite proof will be forthcoming.

During the earliest days of human development, when people lived in what political philosophers have called the natural state, the surplus was derived from fishing, hunting, nut-gathering, berry-picking and root-culture. In this savage, or so-called natural state, the character of the surplus was such as sometimes to call simply for sexual association of labor and sometimes to require personal association of labor. To cite a few examples: for shore-fishing, river-fishing and forest-hunting, nut-gathering, berry-picking and primitive root-culture, sexual association of labor was sufficient, and we find the peoples pursuing these occupations organized accordingly along domestic lines. On the

other hand, sea-fishing and plain-hunting to be successful had to be carried on by clans or cooperating companies of virile males—manly-men, as they were called—and as root-culture advanced from the original essartage methods to the more complicated plantation system, the association of the women and womanly-men was found essential. As far as these latter cases were concerned, therefore, the character of the surplus required personal association of labor and in this way the cooperative system was originally established.

Whether the character of the surplus was such as to require sexual or personal association of labor, in the natural state, the sources of the surplus were far too widespread to admit of monopolization. True, the spawning grounds of fish might be closed in to some extent, but for the most part, fishing, hunting and primitive agricultural opportunities were too far dispersed to be monopolized by any one party within the community to the exclusion of others. As a result, access to the surplus source was not restricted to any particular class. Where the character of the surplus was such as to require only sexual association of labor, there each family had immediate access to the surplus source and the individual members were dependent upon the domestic group for their livelihood. Where the character of the surplus was such as to require personal association of labor, there the cooperating company had immediate access to the surplus source and the individual members were dependent upon the clan for their livelihood. But though in both cases individuals were dependent upon the group to which they belonged, still no one set of individuals was dependent upon another set of individuals for their livelihood. In short, the fact that the surplus source could not be controlled precluded the possibility of coercion and left the cooperative system supreme in the natural state.

During the proprietary period which succeeded the natural state the surplus was derived primarily from cattle-raising and agriculture. For the development of the pastoral surplus personal association was necessary for the defense of the flock and for the occupation and defense of pasture lands, with the result that we find the manly-men of pastoral peoples organized like the hunters of the plain into military companies under a competent chief. For the development of the agricultural surplus personal association of labor was not everywhere necessary. In the temperate zone, where the extensive system of agriculture was most profitable, the land could best be cleared and cultivated by individual families. In the subtropical zone, however, agricultural opportunities were confined to certain favored localities, such as oases, river valleys or lakesides, where irrigation and hoe and spade culture were necessary. These conditions called for intensive agriculture and this in turn necessitated the associated labor of men, women and even children. In summarizing, therefore, we may say that during the proprietary period the

character of the surplus was such as to call for cooperation among pastoral peoples and intensive agriculturists, while among extensive agriculturists the familial or domestic system was found sufficient.

The sources of the pastoral surplus might be monopolized to a considerable extent, since herds of domesticated animals were not goods freely reproducible by labor alone. A single individual or a company of cooperating individuals might by labor alone bring down the wild beasts of the forest and plain, but they could not secure a herd of domesticated animals in this way. Herds and flocks were products of generation and their possession was accordingly confined to the comparatively few who had inherited such stocks from their ancestors. These proprietors were, therefore, in their way monopolists who controlled the pastoral surplus source. As for the rest, they could only gain access to this surplus source by serving the proprietors and receiving in return from them either the products of the existing herd or the nucleus of a new. To the extent, then, that the non-proprietors were dependent upon the herd for their livelihood, they could be coerced by the proprietors. It should be borne in mind, however, that the proprietors were also dependent to some extent upon the non-proprietors for the defense of their herds and pasture lands. For this reason they were forced to mitigate the rigor of coercion in order to secure the advantages of cooperation.

The sources of the agricultural surplus were either widespread or confined. In the subtropical zone where the sources of the agricultural surplus were confined it was a comparatively simple matter for a group of conquerors or usurpers to secure control. In the temperate zone, however, where the sources of the agricultural surplus were spread out over a wide area, monopolization was more difficult. By conquest and through inheritance such control was, however, eventually obtained, except where the surplus was not rich enough to make such monopolization worth while. In both cases when proprietorship was established the disinherited peasants were henceforth dependent upon their landlords for their livelihood, for they no longer had free access to the surplus source. As a result, in agricultural regions the coercive system was established in all its rigor during what we speak of as the feudal ages.

The commercial era may be said to have begun with the differentiation of occupations, the institution of markets and the introduction of coined money. With the resultant development of exchange a new surplus source was opened up whose utility producing capacity was practically boundless, provided appropriate means and methods for its exploitation could be devised. In this enquiry we are concerned with the methods rather than with the means of production, with the system

of organization rather than with the kinds of capital required for the development of the industrial surplus source.

For trade and commerce the familial system was found inadequate from the outset. For handicraft and manufacture also the domestic system was only applicable in certain circumstances and to a limited extent at that. On the whole, therefore, the development of industry and commerce is characterized by the extensive and intensive application of the personal system of association. During the early days of the craft and merchant guilds the cooperative system included all classes of producers, the apprentices, the journeymen and the guild masters. Later on when the wage system was established there was a differentiation of cooperative groups, the apprentices and journeymen cooperating henceforth as industrial laborers, and the masters combining as capitalists in partnerships, companies and corporations. This differentiation of cooperative groups was due to the gradual monopolization of the sources of the industrial surplus. We should accordingly shift our standpoint slightly and study the subject from this side.

At first the sources of the industrial surplus were too widespread to admit of monopolization. As a result, the early guilds were organized along purely cooperative lines. As each guild chose its particular line of production, the then existing surplus sources came in time by custom to be regarded as monopolies of the several guilds. But as every member of the community was allowed to join a guild and rise from apprentice to journeyman, to master, such collective monopolies worked no injury to any one. It had the effect, however, of restricting the normal development of industry. Beyond the limited lines of production controlled by the guilds there were practically limitless industrial opportunities open to those who would work for themselves. This being the case, the guilds—even though they sought and for the most part obtained the support of the state—were not able to hold their artificial monopolies of the surplus sources. Not to go into the history of the subject, suffice it to say that in some countries by revolution and in others through peaceful progress, the older guild privileges were everywhere broken down and industrial opportunities opened to all. In this manner the way was cleared for the development of the competitive system, which was a compromise of the older cooperative and coercive systems, and a transitional stage, as it were, between the two.

Under the new régime the surplus sources were opened to competition, and by the laws of private property each producer was allowed to hold and pass by testament so much of the surplus source as he succeeded in developing. In considering the conditions of this contest it should be noted at the outset that for the development of the industrial surplus organized labor was not enough; a certain amount—

and with the progress of industry an increasing amount—of capital was required. So from the first those that possessed capital had a superior claim to the control of the surplus source, and as industry developed the validity of this claim increased. Those that had labor alone to offer were consequently compelled to work for wages for those who had capital to contribute; but if from their wages the laborers could save enough, they too might become capitalists and enter upon the competitive struggle on their own account. Nor among the capitalists were the conditions of the contest entirely equal. For the development of some surplus sources more capital was required than for the development of others; and again, though as far as the surplus source itself was concerned, small capital could compete with large capital, still by reason of the economy of great organizations the small capitalist might nevertheless be at a disadvantage. So from the first the large capitalist had a superior claim to the control of the surplus source, and with the development of industry the validity of this claim also increased.

From this it is evident that the competitive system must result in the gradual elimination of the weaker competitors until in the end only the strong survive. Indeed, this movement has already gone so far as to be unmistakable, particularly in this land of ours where the competitive system was given the fairest chance to prove its economic efficiency. As the competitive field was gradually restricted, the laborers naturally were first excluded. Though they continued to save, as time went on they found that more and more capital was required to enter into business for themselves, either because the industries in their neighborhood were already absorbed by large capitalists, or because the industries they might still embark upon with their small capital were far removed from their neighborhood. The next to be excluded from the competitive struggle were the small capitalists. As some capitalists secured control of the natural monopolies and others succeeded in establishing artificial monopolies, the small producers were unable to hold their own on the market and one by one they have either been extinguished by or absorbed in the larger concerns, until now, as a matter of fact, only the few strong competitors remain.

Properly interpreted this modern movement so familiar to us all means simply this: the gradual monopolization of the sources of the industrial surplus. Formerly these surplus sources were too widespread to be monopolized, hence the passing existence of the competitive system; but nowadays the ramifications of capital are nearly as widespread as the surplus sources themselves, hence, as I see it, the inevitable recrudescence of the coercive system. By the opening up of new lands through colonization and by the development of fresh surplus sources through invention, this movement has been stayed time

and time again in the past; but as colonies and inventions are immediately monopolized nowadays we need not expect much further obstruction from these factors. It is high time, therefore, that we faced the problem. Instead of trying to stimulate the competitive system, which is really moribund, we should accept the situation as it is and ask what the new coercive system signifies, how long it will last and what system will probably succeed it.

It is a fact beyond dispute, I believe—though I confess with the short space at my disposal I have not been able to present more than passing proof of the fact—that to the extent that the sources of the surplus are monopolized, to just such extent can the monopolizers coerce those shut out of such monopoly. During the middle ages the coercive system was established, as we have seen, through the monopolization of the sources of the agricultural surplus by powerful feudal lords. Being dependent upon the feudal lords for their land, the peasants were deprived of free access to the agricultural surplus source, and could consequently be coerced. In our day the coercive system is being reestablished through the monopolization of the sources of the industrial surplus by the great capitalists. Becoming dependent upon these capitalists for their jobs, wage-earners and salaried men generally are being deprived of free access to the industrial surplus sources and to this extent they too are being coerced. As throughout the middle ages a few free peasant communities remained, so in modern times independent producers persist in some industries. Still as most of the land was feudalized in medieval times, the free peasants existed more by sufferance than by right; and as the main lines of industry are nowadays controlled by great capitalists, the existing independence of the small producer is nominal rather than real.

But freemen have never submitted to coercion with good grace if there was any way to throw off the yoke. For this reason coercion has never proved itself in the end a productive system of association; it runs faster, so to speak, toward the law of diminishing returns than any other system thus far devised. These facts are fundamental and serve to suggest the probable outcome of the existing situation. Let us therefore regard present conditions from this point of view.

As soon as the wage-earners recognized that despite their saving they could not become capitalists, they began at once to present an organized front to coercion. Up to this time the forces of labor had been associated for the purpose of increasing the profits of capital. Henceforth the laborers themselves began to organize their own forces with a view to raising the wages of labor. Trade unionism was the result. It was then that the shield was reversed and the other side exposed to view. It had become evident enough in the past that labor could not develop the industrial surplus source without capital; recently it has

become equally evident that capital can not develop the industrial surplus source without labor. Indeed, one has not to examine the situation very closely to become convinced that the once disfranchised wage-earners are rapidly regaining as organized unions what they lost as individuals, viz., a claim—and a valid claim at that—to some share in the control of the industrial surplus source. To the extent that such claim can be established through association, to just such extent, therefore, can coercion be mitigated. On this account it does not appear to me at all unlikely that capitalists will tire in time of trying to enforce coercive measures, if for no other reason, because they will find coercion in the end too costly. That is to say, with diminishing returns staring them in the face because of the antagonism of trade unionism, I can readily see how capitalists may find it to their advantage to forego exclusive control of their surplus sources and admit their laborers into their monopolies by giving them shares in their companies. And if this movement—which is already well advanced—toward profit-sharing proceeds, ultimately the existing coercive relation between employer and employee will be replaced by the cooperative system, and the old guild organization will be reestablished on a very much larger scale.

But supposing the coercive system between capitalists and laborers to be succeeded in this way by the cooperative system among producers, there is still another class to be considered, namely, the consumers. The new guilds, if established, would differ from the old guilds in this, that they would actually control the headwaters of the industrial surplus, while their predecessors only controlled a few incipient streams. If they chose—and as their profits would be increased thereby they might very well so choose—they could coerce consumers by demanding monopoly prices for their products. Under the existing régime we have had a taste of this sort of coercion as applied by the capitalists alone, we can well imagine, therefore, what it would mean when applied by capitalists and laborers combined. But here again, in spite of present appearances, coercion must in the long run prove unprofitable. The consumers do not represent a particular class, as do the laborers and the capitalists, nor are their interests divided, as are those of the producers. On the contrary, the consumers represent the entire community, and public opinion is always united for fair prices and efficient service. Monopoly prices and poor service touch the public's pocket, as we say, and arouse resistance at once. When things go well enough the consumers are satisfied, but let pressure be exerted on any side by producers, it is remarkable how vigorously they resist. Agitation quickly leads to association, and when combined consumers can readily bring recalcitrant producers to terms, either by boycotting their products, or, if this is not enough, by assuming control of the surplus source themselves. This latter plan has been adopted to a considerable extent in

Europe, where many industries are already municipalized or nationalized, and in our middle western cities it looks as though the trolley companies would pay the same penalty for charging what the people consider high fares.

However we look at it, therefore, the existing system of coercion as applied by the present monopolizers of the social surplus sources appears to be confronted by opposing forces. When pushed too far coercion is met by cooperation and diminishing returns set in. Already cooperation is acting as a powerful check upon such coercion as exists, and as we advance a little further I expect to see the coercive system broken down bit by bit, first by the cooperation of capitalists and laborers in profit-sharing undertakings, and next, where necessary, by the socialization of such industries as prove recalcitrant under the new order of things. Or to put the thought theoretically, I think we may expect the present monopolization of the surplus sources to be extended gradually to admit laborers as well as capitalists, and finally, perhaps, some monopolies to be still further extended so as to admit consumers as well as producers.

THE SHERMAN PRINCIPLE IN RHETORIC AND ITS RESTRICTIONS.

By Dr. ROBERT E. MORITZ,
UNIVERSITY OF NEBRASKA.

FIFTEEN years ago, Professor L. A. Sherman, of the University of Nebraska, while investigating the sentence-lengths used by early and modern English writers, noticed that in the works which he examined each author manifested an average sentence-length, which he inferred to be characteristic of the author. Consecutive hundreds of periods were averaged with respect to the number of words per sentence and the mean of five or more of these averages was taken to represent approximately the average sentence-length used by the author. It was found that the averages for separate hundreds generally varied by less than 20 per cent. from the total average of 500 to 1,000 sentences. The 2,225 periods of De Quincey's 'Opium-Eater' averaged 33.65 ± 6.64 words per sentence, where the number 6.64 indicates the largest number of words by which the averages of individual hundreds differ from the average 33.65. Similarly 722 periods from Macaulay's 'Essay on History' yielded 23 ± 3.35 words per sentence, 750 periods from Channing's 'Self-Culture' 25.35 ± 1.45, 732 periods from Emerson's 'American Scholar' and the 'Divinity School Address' 20.71 ± 2.65 and 805 periods from Bartol's 'Radicalism' and 'Father Taylor' gave an average of 16.63 ± 2.35 words per sentence. These results led to the suspicion that stylists are 'subject to a rigid rhythmic law from which even by the widest range and variety of sentence length and form they may not escape.' Averages from other authors were made with similar results. A culminating test was furnished by actually counting the words in each of the 41,500 periods in the five volumes of Macaulay's 'History of England' with the resulting average of 23.43 ± 7.11. The conclusion was that writers who have achieved a style are governed by a constant sentence rhythm, which will generally be revealed by an examination of 300 periods.

Encouraged by these results, Professor Sherman induced Mr. Gerwig, then a student at the University of Nebraska, to examine other stylistic peculiarities. This Mr. Gerwig did by determining the average number of predications per sentence and the percentage of simple sentences used by one hundred different authors. His conclusions are summed up in the following words: "A very little investigation served to convince me that the same remarkable uniformity which had been

found in the average number of words used by any given author per sentence would also hold in regard to the number of finite verbs, or predications, found in each sentence. The results obtained convinced me also that there was a uniformity in the number of simple sentences per hundred of a given author." Mr. Gerwig expresses his conviction that the average number of predications and simple sentences in five hundred periods of any author who has achieved a style is approximately the average of his whole work. In particular he found that 'while Chaucer and Spenser put habitually over five main verbs in each sentence they wrote, and less than ten simple sentences in each hundred, Macaulay and Emerson used only a little over two verbs per sentence, and left over thirty-five verbs in each hundred simple.'

The theory which has grown out of these investigations has been most tersely stated by Mr. Hildreth, another student of Professor Sherman, who at the same time applies the theory to the Bacon-Shakespeare controversy. We read:

> Ten years or more ago Professor Sherman, while investigating the course of stylistic evolution in English prose, made the discovery that authors indicate their individuality by constant sentence proportions, personal and peculiar to themselves. This was demonstrated especially with the number of words used per sentence in large averagings. It was found that De Quincey, Channing and Macaulay, if five hundred periods or more were taken, evinced this average invariably, and in the earliest as well as in the latest period of their authorship. This discovery led to the suspicion that good writers would be found constant in predication averages, in per cent. of simple sentences, and other stylistic details. Acting upon a suggestion to this effect, Mr. G. W. Gerwig, then a pupil of Professor Sherman, undertook an investigation that established the constancy of predication, as well as simple-sentence frequency, in given authors. . . . Professor Sherman and Mr. Gerwig have thus established by an examination of a great many authors, that writers are structurally consistent with themselves; that they possess a certain sentence-sense peculiarly their own. These investigators have established that by this instinct authors use a constant average sentence-length, and a certain number of predications per sentence, and that a given per cent. of their sentences will be simple sentences. . . . The work of these investigators covers a large amount of material and a wide field of literature. They have examined and compared the works of ancient and recent authors, early and late writings of the same author, and writings of the same author of different character, such as history and dialogue, poetry and prose.* The results thus far obtained are sufficient to show that it is not possible for a writer to escape from his stylistic peculiarities.

The principle once established, its application to cases of disputed authorship is very plain. If each author employs but one set of average sentence proportions such as sentence-length, predication average and simple sentence frequency, it is only necessary to determine these constants for a disputed work and compare them with those of its supposed author. If the two sets of constants manifest a striking differ-

* This Professor Sherman tells me is an oversight. Neither he nor Mr. Gerwig think that the principle in question applies to poetry.

ence, it is conclusive evidence that the supposed author did not write the disputed work; if they are practically identical, the evidence is in favor of the supposed author, for it is highly improbable that two sets of three numbers each, taken at random, should happen to coincide.

Following this or some similar line of thought, Mr. Hildreth examined the prose in fifteen of Shakespeare's plays and of Bacon's 'Essays' and a portion of the 'New Atlantis.' To eliminate possible errors arising from careless or inconsistent punctuation, all the material was repunctuated according to modern principles. All inorganic and broken sentences were omitted. Then follow twelve pages of figures representing totals and specimen results, and then the summary.

SUMMARY.

	No. of Sentences Examined.	No. of Words per Sentence.	No. of Predications per Sentence.	Per Cent. of Simple Sentences.
Shakespeare......	5,002	12.39	1.70	39
Bacon...............	2,041	32.59	3.45	14

The reader is left free to draw his own conclusion from these figures. The closing statement is that the numbers are not presented as proof conclusive, but only as contributory evidence in the controversy.

Without wishing to deny the general principle of sentence-rhythm, which, in honor of its discoverer, I shall refer to as the Sherman principle in rhetoric, I wish to point out certain limitations to this principle, which I think will invalidate the conclusion that must otherwise be drawn from the above summary. The Sherman principle has been established only for certain normal forms of composition, a fact which has been overlooked in the statement of the principle, as well as in its applications. What has been shown is that a writer uses definite sentence proportions while writing in a certain form of composition; it has not been shown that he uses the same proportions when he employs essentially different forms of composition, such as drama and description, criticism and correspondence. It is almost obvious that the sentence proportions of a philosophic discourse must differ from those employed in light fiction or the drama, yet this fact is not only overlooked, but directly denied in Mr. Hildreth's statement of the Sherman principle. To compare the sentence structure of dramatic compositions with the sentence structure of a heavy dissertation or description is to compare the oral utterances of a person engaged in deep contemplation or in vivid imagination of some sublime object with the commonplace talk of the drawing-room or the vernacular of the marketplace. Quite as plausible would it seem to assert that a man's average gait in walking is the same whether he is out for pleasure, on business, to escape from danger, or on a long journey.

The chief fact which apparently gives weight to the persistence of sentence proportions, regardless of the composition employed, is the instance of Macaulay's 'History of England,' for which the sentence constants are practically the same as those of his essays, notwithstanding that some parts of the 'History,' in particular the second volume, contain much dialogue. This anomaly is explained by the fact that taking the five volumes as a whole the essay style predominates to such an extent as practically to obliterate the disturbing effect of the dialogue portions. This is easily demonstrated. The average sentence length of 'Macaulay's History' is 24.43, which differs but little from 23.65 of Machiavelli, 24.00 of Pitt and 23.00 of the 'Essay on History'

VARIATION OF SENTENCE-LENGTH IN TEN AUTHORS.

	No. of Sentences.	Average Number of Words per Sentence.					
		First 100.	Second 100.	Third 100.	Fourth 100.	Fifth 100.	Av. of 500.
Swift.							
'Polite Conversation'......................	500	10.8	12.0	12.1	13.7	13.6	**12.4**
'Essay on the four last years of Queen Anne'.	500	51.6	49.3	58.2	62.1	53.0	**54.8**
Dryden.							
'The Mock-Astrologer'......................	500	15.0	16.5	19.6	17.1	16.3	**16.9**
'Essay on Satire'..........................	500	45.0	48.1	40.1	44.8	33.3	**42.3**
Goldsmith.							
'She Stoops to Conquer'....................	500	13.9	13.1	13.2	14.9	12.4	**13.5**
'The Vicar of Wakefield'...................	500	31.2	30.8	27.5	25.8	26.5	**28.4**
'Present State of P. Learning in Europe'....	500	30.4	24.6	25.7	23.5	20.4	**24.9**
Scott.							
'Life of Napoleon'.........................	500	46.0	47.0	50.0	49.8	46.5	**47.9**
'Auchindrane'..............................	500	19.1	21.9	23.9	19.2	21.8	**21.2**
'Ivanhoe'..................................	500	46.2	35.3	33.7	29.8	32.2	**35.4**
Carlyle.							
'Signs of the Times,' etc..................	500	27.4	31.8	26.9	34.5	42.3	**32.6**
'The Hero as Divinity'.....................	500	25.2	21.5	24.3	23.5	23.4	**23.6**
Bayard Taylor.							
'The Prophet'..............................	500	15.8	11.8	11.3	14.8	16.4	**14.0**
'Balearic Days'............................	500	30.3	29.3	27.8	26.6	27.6	**28.3**
Lowell.							
'Letters,' Vol. II.........................	500	18.8	18.2	22.5	21.8	17.2	**19.7**
'Fable for Critics'........................	180						**96.6**
Holmes.							
'Guardian Angel'...........................	500	26.4	29.0	32.2	31.1	25.6	**28.9**
'The Autocrat at the Breakfast Table'.......	500	19.7	18.8	18.0	23.8	20.1	**20.1**
Longfellow.							
'The Spanish Student'......................	500	12.0	8.8	11.1	8.8	10.1	**10.2**
'Hyperion'.................................	500	20.5	25.4	27.5	24.3	21.3	**23.8**
Schiller.							
'The Robbers'*.............................	2500	12.2	11.4	12.6	10.2	10.9	**11.5**
'History of Thirty Years' War'.............	500	29.9	27.8	28.3	24.9	25.7	**27.3**

* The averages except the last are for 500 periods.

by the same author. Now of the 41,500 periods of the 'History,' there are forty-five hundreds whose average is less than twenty words per sentence. These we may take to represent the dialogue portions of the work. The exact average of these 4,500 periods is 18.62 words per sentence, that is, 4.81 words per sentence less than the average for the entire 'History.' If we replace these sentences by others of normal length, we augment the total aggregate by 4,500 times 4.81 or 21,645 words. That is, if the portions of the 'History' which contain an excessive amount of dialogue were replaced by an equal number of sentences of normal length, the five volumes would contain 41,500 × 23.43 + 21,645 or 993,990 words. Dividing this number by 41,500 we obtain 23.95 words per sentence, a result not essentially different from the actual average, 24.43.

But whether the presumption is for or against limitations of the Sherman principles is of little consequence in a matter so easily tested by experiment. I have prepared a table giving the approximate sentence-lengths for widely divergent forms of composition by the same author. The averages by hundreds, as well as the final average, have been given in order to show the variation in the averages of consecutive hundreds in each work.

It is needless to continue this table, for a mere inspection of the figures already given must once and for all settle the 'single set of constants' theory. In fact the question suggests itself, whether the number of different sets of constants which an author may employ is not limited merely by his versatility as a writer. So far as sentence-length is concerned, this conjecture is fully corroborated by a partial examination of Goethe's works. The results are exhibited in the following table:

VARIATION IN THE SENTENCE-LENGTH OF GOETHE'S WRITINGS.

Title of Work.	No. of Sentences.	Average Number of Words per Sentence.					
		First 100.	Second 100.	Third 100.	Fourth 100.	Fifth 100.	Av. of 500.
'Der Buergergeneral'	500	6.7	5.1	4.5	3.9	4.7	**5.0**
'Goetz v. Berlichingen'*	2500	8.7	9.2	8.7	7.8	8.1	**8.5**
'Letters to Frau v. Stein'	500	13.5	12.5	11.3	11.2	12.4	**12.2**
'Faust': First Part	500	14.6	15.2	13.6	13.0	12.0	**13.7**
'Faust': Second Part	500	16.3	17.2	15.5	12.3	16.5	**15.6**
'Reinecke Fuchs'	500	18.5	16.5	16.9	14.8	16.6	**16.7**
'Die Leiden d. j. Werthers'	500	20.7	20.9	19.1	22.7	18.2	**20.3**
'Italiaenische Reise: Rom'	500	23.1	23.7	22.7	21.5	22.7	**22.7**
'Die Wahlverwandtschaften'	500	21.9	23.6	23.7	25.1	24.5	**23.4**
'Briefe aus der Schweiz'	500	23.2	26.5	25.6	23.0	28.4	**25.3**
'Entwurf einer Farbenlehre'	500	28.4	25.7	29.3	22.3	26.1	**26.4**
'Bildhauerkunst'	500	27.1	32.9	33.7	27.0	36.9	**31.5**
'Dichtung u. Wahrheit'	500	31.5	36.1	30.9	28.9	31.1	**31.7**
'Metamorphose d. Pflanzen'	288	33.8	34.1				**33.7**
'Literatur: Recensionen'	500	37.3	32.9	36.9	31.7	34.9	**34.7**

* The individual averages are for 500 periods each, the total for 2,500 periods.

The above list includes romance, drama, allegory, criticism, biography, description, science and correspondence, but with the exception of 'Faust' and 'Reinecke Fuchs' the works are all in prose, so that the fact of variation is not disturbed even if we consider prose literature alone. There can be little doubt that a complete examination of Goethe's writings would furnish a chain of sentence-lengths varying by almost insensible gradations from five to thirty-five or forty words per sentence.

The conclusion from which there seems to be no escape is that the average sentence-length used by an author depends upon at least two factors, one of which is the author's sentence sense, the other the particular form of composition into which his thought is cast.

What is true of sentence-length holds equally true of predication averages and simple sentence percentages. Other things being equal, the shorter sentences will naturally contain the fewer predications, and a larger per cent. of simple sentences, the limits being single predications, on the one hand, and none but simple sentences, on the other. This general relation is fully made good by the facts. Macaulay, in his 'History of England,' uses 23.3 words per sentence and 2.3 finite verbs, which is almost exactly ten words to one verb. Nearly the same ratio obtains in More's 'Life of Richard III.' with an average of 3.65 verbs out of 36.5 words per sentence; Hooker's 'Ecclesiastical Polity,' with an average of 4.12 verbs and 40.9 words per sentence; Sidney's 'Defense of Poesie,' 3.98 verbs and 39.3 words per sentence; and Channing's 'Self-Culture' employs 2.57 verbs out of a total of 25.9 words per sentence. However, in very short sentences there is a tendency to diminish and in very long sentences to increase the ratio of the total number of words to the number of verbs per sentence. Thus Emerson in his 'Divinity School Address' uses 2.14 verbs and 18.0 words per sentence, while Hakluyt in the 'Voyages of the English Nation to America' uses but 4.44 verbs out of an average of 56.8 words per sentence.

A more striking though less obvious relation exists between predication averages and simple sentence percentages, which is all the more surprising, inasmuch as simple sentence percentages are the least constant of the sentence proportions thus far examined. For instance, Lyly's 'Euphues' furnishes for five consecutive hundreds 26, 14, 20, 15 and 8 simple sentences respectively. De Quincey's 'Opium-Eater' yields the numbers 10, 19, 15, 7 and 21 for consecutive hundreds, and Macaulay in his 'History of England' gives simple sentence percentages as widely divergent as 41 and 27, though each average is based upon 500 consecutive sentences. These are extreme cases, but even the average variation is high. An examination of fifty authors shows that the simple sentence percentages based upon an examination of 400 sentences, differs

on an average by nearly 6 per cent. (5.98 per cent.) from the averages based upon 500 sentences from each author, with extreme variations as high as 28.8 per cent. It seems quite plain, therefore, that several thousand sentences from each author would have to be examined to get anything like a constant simple sentence percentage.

Now Mr. Gerwig's tables* for predication averages and simple sentence percentages for prose works comprise averages of about 60,000 sentences taken from seventy-one different authors, exclusive of the complete averages for Macaulay's 'History.' These tables I utilized for a preliminary test† by employing the following device. I grouped together all the works whose predication averages fell between 1.50 and 2.00 per sentence. This group yielded an average of 1.83 predications per sentence and 53 simple sentences per hundred. Next I averaged the works which contained between 2.00 and 2.25 predications per sentence, and the average for this group was found to be 2.15 verbs per sentence and 38 simple sentences per hundred. Proceeding similarly by grouping the works whose predication averages fall between 2.25 and 2.50, between 2.50 and 2.75, and so on, we obtain the following table:

Index.	Predications per Sentence Between.	Averages.		$P\sqrt{S}$
		P	S	
1	1.50 and 2.00	1.86	53.0	13.54
2	2.00 " 2.25	2.14	39.1	13.38
3	2.25 " 2.50	2.34	32.9	13.41
4	2.50 " 2.75	2.62	25.9	13.33
5	2.75 " 3.00	2.88	23.2	13.87
6	3.00 " 3.25	3.10	19.2	13.59
7	3.25 " 3.50	3.39	15.9	13.52
8	3.50 " 4.00	3.70	13.4	13.55
9	4.00 " 4.50	4.17	10.0	13.19
10	4.50 " 5.00	4.84	8.3	13.94
11	5.00 " 5.50	5.38	6.7	13.92

The numbers P, the predication averages, and S, the simple sentence percentages, aside from the general reciprocal relation which we should expect, manifest a more specific uniformity. The square-root of 53, the first number under S, multiplied by 1.86, the corresponding number under P, is 13.+, but so also is the square-root of 39.1, the second number under S, multiplied by 2.14, the corresponding number for P. Similarly for the third, fourth, fifth pairs of corresponding numbers. That is, we find

$$1.86\sqrt{53.0} = 13.+$$

$$2.14\sqrt{39.1} = 13.+$$

* 'University (of Nebraska) Studies,' Vol. 2, No. 1.

† For a detailed discussion of this experiment, together with other matter of a more technical nature, see 'University Studies,' University of Nebraska, Vol. III., No. 3.

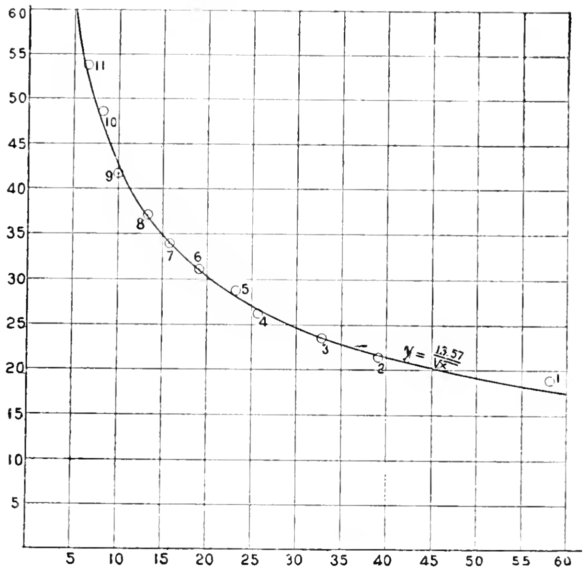
$$2.34 \sqrt{32.9} = 13. +$$
$$2.62 \sqrt{25.9} = 13. +$$

and so on through the list, the result in each case being 13. +. In short, we have quite uniformly

$$P \sqrt{S} = C,$$

where $C = 13.57$, the arithmetic mean of the slightly varying values 13. +, which are given in the last column of our table.

How nearly this equation fits our data may be best seen from the graphical representation, Fig. 1. The curve $P \sqrt{S} = 13.57$, as well



as the P's and S's from our table, have been plotted in rectangular coordinates by using the values of S for abscissas, and for ordinates ten times the corresponding values of P. The resulting points have been numbered to correspond with the index numbers in our table.

The relation expressed by $P \sqrt{S} = C$ may be easily expressed in words. For if P_1 and P_2 represent two predication averages, and S_1, S_2, the corresponding simple sentence percentages, we have approximately

$$P_1 \sqrt{S_1} = C = P_2 \sqrt{S_2}$$

from which

$$P_1 : P_2 = \sqrt{S_2} : \sqrt{S_1}$$

that is:

The predication averages of various works are approximately inversely proportional to the square-roots of their simple sentence percentages.

It will be interesting to test this law on some specific work, not included in the table from which the law has been deduced. Macaulay's 'History of England' is the only larger work whose sentence dimensions have been determined with reasonable accuracy. Here S was found to be 34.2, and substituting this in our formula we find

$$P = 13.57 \div \sqrt{34.2} = 2.32$$

which is nearly equal to the value 2.30 as determined by actually counting the finite verbs in 40,000 sentences.

There is, of course, no reason to infer that our formula will apply with equal accuracy to the sentence dimensions of every other work. Variations from it must occur. The only conclusion that is warranted is that when a reasonable number of works are selected whose predication frequency is nearly the same, and the average of these frequencies is taken, this average will bear a definite relation to the average of simple sentence ratios of the same works and that this relation is approximately expressed by our formula.

EDUCATIONAL ENDOWMENTS AT THE SOUTH.

BY ELIZABETH M. HOWE.

WITHIN the past five years alone the benefactions to institutions of higher learning in the United States have amounted to a little more than sixty-one millions. That is to say, during that time money from private sources has been devoted to liberal education at the rate of a little more than a million dollars a month. In many cases, it must be admitted, the claim of the institutions thus favored to the rank of college or university is not very substantial, but the gifts themselves represent the loyalty of the donors to a certain ideal of education, however imperfectly that ideal may have expressed itself.

At first it would seem that this flood of gold, the high tide of a stream that began to flow about thirty years ago, could have left no need of the higher education unprovided for; but as usual a closer survey of the field shows not only many a nook not yet irrigated, but whole fields still arid and uncared for. Educational endowments have this in common with other investments, that they follow usually the line of greatest immediate efficiency; they are also controlled in a high degree by sentiment, and the two have so reinforced each other here in America as to turn great streams of wealth in certain directions, while but scanty dribbles have flowed in others. The habit of giving began to establish itself soon after the civil war, and the greatest beneficiaries during these intervening years have been the young men of the New England and north central states. The next most favored class have been the young men and women of the middle states and the west; least of all has the white population of the south profited by this generosity. And by the white population we do not mean the 'poor whites,' nor the mountaineers, nor the 'crackers,' nor any other class traditionally aloof from educational influences, but the white race *in toto*. 'The south,' also, should be defined. For our purpose here it means the ten cis-Mississippi slave states and Louisiana, since the slave states further west have been subjected to influences which have left the first group untouched.

Looking through the list of institutions of the higher learning issued by the Bureau of Education at Washington—a list which is comprehensive rather than critical—we find the advantage in every respect but one with the north. That advantage, to speak politely, is in the number of universities and colleges of liberal arts themselves. Massachu-

setts reports nine and so does Alabama; Rhode Island has one and Connecticut three, but North Carolina has fifteen, Georgia and Virginia each eleven and Tennessee twenty-four. Yet out of a total of 157 millions of productive funds held by American colleges, the south has but fifteen; of eight and a half million books in college libraries, the south holds but one and a quarter millions; the value of her scientific apparatus is a little over a million against a total valuation of seventeen millions, and of grounds and buildings eight and a half millions in a total of 146 millions. The total annual income available for the higher education in Virginia, North and South Carolina, Georgia, Alabama, Mississippi, Louisiana, Tennessee and Kentucky is nineteen thousand dollars less than the yearly income of Harvard University. The efficiency of this income is still further reduced by being divided among a multitude of institutions. Ten feeble colleges are a poor substitute for one strong one. Out of forty institutions in the United States with productive funds amounting to a million and over, but five are in the south; of twenty-one with productive funds of between half a million and a million, but one. As to colleges for women, in 1890 sixty-eight per cent. of all such institutions—classing as colleges institutions empowered to give degrees—were in the south, while seventy-eight per cent. of the endowment of that group of institutions was held by twelve colleges in the North Atlantic states. The increase of endowment for women's colleges since that date has been preponderantly in institutions at the north.

So far as can be gleaned from public records, there are three southern state universities which in thirty years have received no 'benefaction' whatsoever. It is true that in 1878 one of them reported hopefully that it had received some samples of cotton in different stages of growth, and some silk cocoons, but the visions of prosperity thus evoked were not fulfilled. Another term of barren years set in, and though as an emblematic gift—the substance of things hoped for—the cocoons were most happy, as an educational endowment they left much to be desired. Occasionally the southern college not otherwise favored has reported a gift of books, but there has been an ominously large proportion of 'public documents' in these lists, and libraries of country clergymen—hardly treasuries of modern thought, it is to be feared. These facts show another difference, in addition to the quantitative one, between the educational opportunities which have been open to the young men and women of the north and south.

The usual way of meeting an array of facts such as these is to refer to Mark Hopkins on his log as the true measure of the quality of a college, but unfortunately in no way does a scanty endowment tell so against an institution as in securing able teachers. The greatest scholarship, the exceptional ability in teaching, the strong and winning

personality gravitate through urgency of demand to the great centers. Moreover, the abnormal conservatism of the south, both political and religious, creates an atmosphere antagonistic to the finer interests of scholars.

Superficially speaking, liberal training is an unimportant factor in the problem of general education; it is the elementary school that counts. But here again we find a deplorable contrast between the south and other parts of the country. In 1900 the average length of the school year in the southern states was but 109 days, the average expenditure per pupil \$9.72. In the north central states—new states, many of them—the average expenditure per pupil was \$20.85. We must remember, too, in connection with these statistics, that the border states, such as Maryland and Tennessee, bring up the average enormously. In North Carolina 'school kept' but a fraction over seventy days, and the expenditure per pupil was \$4.34. In Alabama, though the school year was eight days longer, the expenditure per pupil was but \$3.10, and so small is the enrolment through the southern states, that at the Conference for Education in the South held in 1901, the average number of school days per child was given as three a year. Be it remembered, too, that these children, the men and women of to-morrow, thus on starvation rations scholastically, are without other means to relieve their necessities. There are no 'vacation schools,' no lectures, no libraries, one might almost say no books passing from hand to hand. They are without the stimulus of contact either with active life or with a considerable number of well-educated people; and as they grow to maturity they are too often without occupation, except of the most restricted and uneducative kind. According to Mr. Walter H. Page, the proportion of illiterate white voters in the ten cis-Mississippi southern states is to-day as large as it was in 1850. That is to say, in all these years of marvelous educational development in other parts of the country, and in which even the black, just out of slavery, has so progressed, the southern white has not gained; indeed, he has lost, since he staggers to-day under the incubus of half a century of apathy. We are accustomed to take the 27 per cent. of the census as representing the illiteracy of the old slave states, but that is a very incomplete measure. At least an additional 25 per cent. can do no more than read and write, and the upper level of intellectual equipment and efficiency is below that of the corresponding classes in other parts of the country. Yet upon these men and women devolves the most critical and complicated social problem ever given to a community to solve, one demanding above all else that it be seen clearly and seen whole, and requiring for its solution nothing less than statesmanlike

methods, a wide social philosophy and the finest ethical feeling translated into terms of democracy.

What are the reasons for these lamentable and even tragic conditions? First, certainly, are those so often noted—poverty and a scanty population. The proportions of area and school population might be placed at forty children per square mile in Rhode Island and forty square miles per child in Florida—a condition which gives the former commonwealth an advantage in developing a system of public schools. But back of this and back of the terrible losses of the civil war lies another which has made the first two effective for harm—heretofore the south has not desired any general development of education within her borders. At the time that John Eliot in Massachusetts was praying, 'Lord, for schools everywhere among us,' Governor Berkeley of Virginia, in answer to an inquiry from England, was writing, 'I thank God there are no free schools nor printing presses; God keep us from both.'

William and Mary made a promising beginning. It was established as a school for the Virginia people and the Indians, with an endowment munificent when compared with that of Harvard and Yale at that time. "But," to quote a southern educator, "the idea that education was *not* for the masses did not die an easy death in Virginia; and William and Mary was never a people's school in the sense that Harvard and Yale were. * * * The years following the Revolution saw the defeat of every plan for universal education. Most of the provisions were merely permissive, and the whole atmosphere was antagonistic. The noble plan of Jefferson was too liberal to be even proposed in its entirety, and the part which was made public was so mutilated in the process of adoption that it became an object of contempt."

At the outbreak of the civil war the provision for education below the grade of college was sporadic and infrequent, nor, with the possible exception of the University of Virginia, was there a single college in the south to compare with those of the north. It is necessary to keep these things in mind—the habit of neglect, the established indifference, the educational poverty, both of thought and endowment—if we are to understand the conditions to-day. To those must be added that self-satisfied habit of mind which has always been one of the south's heaviest handicaps. It was with such a history as this that the south had to meet the terrible conditions at the close of the civil war, and it is these traditions which are largely responsible for the tragic mistakes of these later years.

'Why should the children go to school?' asked a South Carolina mother. 'Every one in the county knows who we are.' So the children did not, and to-day are lounging through life in frayed and listless poverty. Even in towns where there was a less open avowal of the doc-

trine that to be known by your neighbors is a liberal education, the attempts at schooling in the later sixties and early seventies presented many picturesque variations from the usual type. The early morning hours would see sedate horses bestridden by from three to five children each making their way into town to deposit their load at a dame school, sometimes a dame school of delicate and antiquated refinement, and sometimes one of a rather hot-handed domesticity, where the boys were cuffed through geography and fractions. These schools sprang usually from the teacher's need instead of from her ability; almost invariably was she without professional training and without educational standards, and too often even without any but the most meager schooling. Such institutions quite deserved the practical disregard in which they were held. Their potent influence—for they exercised one—was not upon the reluctant children within their walls, but upon the community without, for whom they alone represented learning, knowledge, the great society of scholars. It was with such educational standards, perhaps we should say also such educational habits, as these that the generation born just after the war grew up; they knew such schools or none at all; and it was not the child of the poor white alone who depended upon them, but the children of all classes, outside of the chief cities. For many a year after the close of the civil war the shrunken and disheveled libraries lay neglected in the dignified old houses; other cares than those of literature absorbed their owners and their owners' sons and daughters. The *res angustae domi* were studied at first hand, instead of through the medium of Latin authors, and it was full twenty years after, in many cases, before the ruling group of people, even in many of the most favored parts of the south, sent a son to a college of exacting standard and liberal equipment. Their daughters they are hardly sending even now. It is the men and women of that bereft generation, shorn of the family distinction of the past, lacking the discipline of the civil war itself, so royally met by so many southern men and women, and growing up with little or no education who are now in the saddle. Is not this the key to many of the lamentable social conditions in the south to-day? Is the persistent medievalism of thought any but a logical outcome?

In so comprehensive a range of needs it would seem difficult to single out any as specially vital, and it is true that educational endowment for the south can hardly go amiss. But there are certain strategic points which it is especially desirable to gain. The first of these is the development of industrial training. For many a year to come, if not for many a generation, the south must be essentially a rural population, and if the dormant mind is to be reached, it must be through the things with which it is in daily contact. One of the ways to dignify labor is to

make it interesting, and probably no one thing would do more to efface the lingering class distinctions of the south than a well developed and widespread system of industrial education. The man or woman who has skill in your own handicraft commands your respect, no matter who his forebears may have been, and the guild, even though it be unorganized, founded on some form of mental comradeship, is an efficient corrective for many unwholesome class distinctions. Industrial training is also preeminently valuable to the south because it is based on science. To acquire it is to acquire inevitably to some degree the scientific habit of thought, that is to say, the habit of thought which not only demands facts but respects them, and to which law means not the whim of man, but the unrelenting edict of nature with all its inevitable penalties. To displace even an *à priori* theory of how to make hens lay by one based upon an open-minded study of facts, is to make an advance in methods of thinking which must ultimately react upon other things than hens. The calm and impersonal methods of science, once given a foothold, even in the dairy or the poultry yard, must in the end dislodge that impassioned *à priori* reasoning which has been the bane and weakness of the south for so many generations. But the teaching of science is expensive; it means laboratories and experiment stations and provisions for individual work. It means, in short, those endowments in which the south is deficient.

The second strategic need is for the best possible normal training. The lamp of learning, if learning it can be called, has been passed on in one southern hamlet and another from gentlewoman to gentlewoman, who has brought to her work the traditions of culture, the refinement and the care-taking habit which were her birthright. Thirty years ago she was not greatly behind teachers in other parts of the country in professional training—since practically no one had any—but each year since then has put her at a greater comparative disadvantage. Nothing in the history of the south is more promising than the eager desire for professional education which many of its teachers are now showing, and, in so far as they come from the old ruling class, they have the power to confer upon their public a double benefit. A certain condescension towards teachers is apt to linger in the minds of a commercial community, in spite of fervent lip-service. But when the teachers come largely, as they are apt to do in the south, from the class which represents the most deeply rooted traditions of a community, that phase of crudity may be short lived, if not altogether avoided.

The third need of the south is a cordon of secondary schools, financially independent of their patrons. They may be independent as the public school is independent or they may be made so by endowment, but independent they must be, if they are to do their best work. This is an inviting field for endowment, as $100,000 will do for a school what

a million will hardly do for a college. The best solution of the problem of the secondary schools in the south is the concentration of the strength of a community upon its public schools, since to keep them at a creditable level is to help to the solution of more questions than can be reached in any other way. The endowed private school, on the other hand, has the great advantage of being out of politics and having a freer hand in working out its development than is possible to a public school in a community of lax or unformed educational standards. In either case, the point is to secure to the school freedom to select its teachers without political or denominational dictation, and to make it strong enough to impose its standards upon a reluctant community.

Finally, the interdependence of school and college is such that neither can do its best work alone. The college rests upon the school as the house on its foundations, and without the college standards by which to test its work the school loses a powerful stimulus. With the utmost generosity on the part of our philanthropists which can be looked for, even in these lavish days, the southern colleges must remain for many years inferior to those of the north in equipment and as a whole in teaching force. Yet they represent for the great mass of the young men and women in their respective communities the best that is open to them, and, too often, all that can be desired. Probably as valuable a gift as could be made to the south just now, and one requiring a comparatively small fund, would be the establishment of a group of scholarships especially for young southern men and women, available in different institutions in the north. Let us imagine the competitive examinations for such scholarships held at Raleigh for the young men and women of the Old North State, at Columbia, South Carolina, for the students of that state, at Augusta, Jacksonville, Mobile. Not only would every ambitious boy and girl in the state be aroused, but the spur of opportunity would be felt in every school with a spark of life in its management, and there would be the impact upon the very centers of growth of new habits of thought.

'The south has no reason to be ashamed of its traditions,' said a dignified and able southern woman who had done good service for education, when such a plan was broached in her hearing. But by the time that one of her sons had graduated at Harvard and another at Cornell, and her daughter was hard at work at Vassar and her niece at Pratt, she would see that no question of traditions, in the sense in which she felt them threatened, was involved. On the contrary, what is best in the distinctive characteristics of the south can not be preserved by men and women of belated minds, and one of the services which we ask of that part of the country is that those finer elements shall be preserved and made a part of our national life. The present demand for industrial education in the south, too, which is making

itself heard so clearly from so many directions, makes the need of some provision for the best liberal training the more necessary; for unless industrial education is informed and guided by such a spirit, the abyss of a dull utilitarianism awaits it.

The Spanish-American war revealed the south of these later days to itself. It gave—O happy gift!—a new point from which to reckon time, and showed how far, unknown to themselves, the old slave states had moved since Appomattox. A tide of vigor swept through villages and hamlets, bringing them, for the first time in a generation, in contact with the life of the world. It is not fanciful to attribute the educational awakening of the south to-day in part, at least, to that contact with outside affairs—to the sense of oneness with a great nation. But whatever the cause, the fact is here to reckon with—a desire for education throughout the south such as it has never known, and it is being sought in many cases in the face of great difficulties and at the cost of noble sacrifice. Many a southern man and woman, to-day buried in obscure villages, have fairly earned a brevet for gallantry in action in the struggle with stifling social conditions. There is no more present duty for the American people than to uphold their hands. When a community's poverty, born of its ignorance, is such that the tax levy yields but $18 a year for schools, the vicious circle must be broken from outside. The state must care for those hamlets which can not care for themselves, and by a parity of reasoning, the needs of the south are a charge upon public-spirited men and women everywhere. The response should be prompt and abundant. With the new-born desire for education, the line of greatest efficiency for educational endowments is shifted to the south; the need there is great and basal—and they are next of kin.

HERTZIAN WAVE WIRELESS TELEGRAPHY. V.

By Dr. J. A. Fleming, F.R.S.,

Professor of Electrical Engineering, University College, London.

Quite recently, Sir Oliver Lodge and Dr. Muirhead have employed as a self-restoring coherer or kumascope a steel disc revolved by clockwork, the edge of which just touches a globule of mercury covered with a thin film of paraffin oil. The contact is made between the mercury and the steel by the electric wave generating an electromotive force in the aerial, sufficient to break through the thin film of oil. When the wave stops, the circuit is again interrupted automatically.

This device is used without a relay to actuate directly a syphon recorder as used in submarine telegraphy. The working battery employed with it must only have an electromotive force of about a tenth of a volt. It may be used also with a telephone in circuit and can therefore be employed either for telegraphic or telephonic reception.*

One of the most sensitive of these self-restoring kumascopes is the carbon-steel-mercury coherer, the invention of which has been attributed to Castelli, a signalman in the Italian Navy,† but also stated on good authority to have been the invention of officers in the Royal Italian Navy, and has therefore been called the Italian Navy Coherer.‡ This instrument has been arranged in several forms, but in the simplest of these it consists of a glass tube, having in it a plug of iron and a plug of arc-lamp carbon, or two plugs of iron with a plug of carbon between them. The plugs of iron, or of iron and carbon, are separated by an exceedingly small globule of mercury, the size of which should be between one and a half and three millimeters. The plugs closing the tube must be capable of movement, one of them by means of a screw, as shown in the diagram (Fig. 17), taken from a patent specification communicated to Mr. Marconi by the

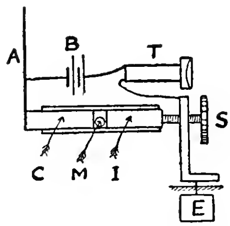


Fig. 17. Italian Navy Self-Restoring Kumascope. *C*, carbon plug; *I*, iron plug; *M*, mercury globule; *A*, aerial; *B*, battery; *T*, telephone; *S*, adjusting screw.

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* See *Proc. Roy. Soc. London*, Vol. LXXI., p. 402.

† See Report by Captain Quintino Bonomo, 'Telegrafia senza fili,' Rome, 1902; *L'Elettricista*, Ser. II., Vol. I., pp. 118, 173.

‡ See Royal Institution, Friday evening discourse, by Mr. Marconi, June 13, 1902. Also *The Electrician*, Vol. XLIX., p. 490. Also a letter to the *Times* of July 3, 1902, by the Marchese Luigi Solari.

Marchese Luigi Solari, of the Royal Italian Navy. One of the plugs of this tube is connected to the aerial and the other to the earth, and they are also connected through another circuit composed of a single dry cell and a telephone. The arrangement then forms an extremely sensitive detector of electric waves or of small electromotive forces, or, if a wave falls on the aerial, the electromotive force at once improves the contact between the mercury and the plugs and therefore causes a sudden increase in the current through the telephone, giving rise to a sound; but when the wave ceases, or the electromotive force is withdrawn, the resistance falls back again to its origin value, and the arrangement is therefore self-acting, requiring no tapping or other device for restoring it to receptivity.

A very ingenious form of combined telephone and coherer has been devised by T. Tommasina.* In this instrument the diaphragm of an ordinary Bell telephone carries upon it a very small carbon or metallic coherer. This coherer is connected in between the aerial and the earth, and is also in circuit with a battery and the electromagnet of a telegraphic relay. When this relay operates it closes the circuit of another battery which is placed in series with the telephone coil. The moment the current passes through the telephone coil it attracts, and therefore vibrates, the diaphragm and shakes up the metallic filings. If an observer therefore places the telephone to his ear, he hears a sound corresponding to every train of waves incident upon the aerial. With this arrangement, one can obtain two different kinds of results, according to the nature of the cohering powder placed in the cavity in the diaphragm. First, if the powder consists of a non-magnetic metal, gold, silver, platinum or the like, the receiver will be very sensitive: and at the same time the current passing through it when it is cohered will be sufficient to work a sensitive recording apparatus in series with the telephone coil. Secondly, if the metallic powder placed in the cavity is a magnetic metal, the receiver will be somewhat less sensitive, but will work with more precision, because of the magnetic action of the magnet of the telephone upon the cohering powder. If no recording apparatus is used, the observer must write down the signals as heard in the telephone, since corresponding to a short spark at the transmitting station, a single tick or short sound is heard at the telephone, and corresponding to a series of rapidly successive sparks, a more prolonged sound is heard in the telephone. These two sounds, as already explained, constitute the dot and the dash of the Morse signals.

We may, in the next place, refer to that form of kumascope in which the action of the wave or of electromotive force is not to decrease the resistance of a contact, but to increase that of an imperfect contact. As already mentioned, Professor Branly discovered long ago that

* See U. S. A. Patent Specification, No. 700,161, May 24, 1900.

peroxide of lead acts in an opposite manner to metallic filings, in that when placed in a Branly tube it increases its resistance under the action of an electric spark, instead of decreasing it. Again, Professor Bose has found that fragments of metallic potassium in kerosene oil behave in a similar manner, and that certain varieties of silver, antimony and of arsenic, and a few other metals, have a similar property. Branly tubes, therefore, made with these materials, or any arrangements which act in a similar manner, have been called 'anti-coherers.' The most interesting arrangement which has been called by this name is that of Schäfer.* Schäfer's kumascope is made in the following manner: A very thin film of silver is deposited upon glass and a strip of this silver is scratched across with a diamond, making a fine transverse cut or gap. If the resistance of this divided strip of silver is measured, it will be found not to be infinite, but may have a resistance as low as forty or fifty ohms if the strip is thirty millimeters wide. On examining the cut in the strip with a microscope, it will be found that the edges are ragged and that there are little particles of silver lying about in the gap. If then an electromotive force of three volts or more is put on the two separated parts of the strip, these little particles of silver fly to and fro like the pith balls in a familiar electrical experiment, and they convey electricity across from side to side. Hence a current passes, having a magnitude of a few milliamperes. If, however, the strip is employed as a kumascope and connected at one end to the earth and at the other end to an aerial, when electric waves fall upon the aerial, the electrical oscillations thereby excited seem to have the property of stopping this dance of silver particles and the resistance of the gap is increased several times, but falls again when the wave ceases. If therefore a telephone and battery are connected between two portions of the strip, the variation of this battery current will affect the telephone in accordance with the waves which fall upon the aerial, and the arrangement becomes therefore a wave-detecting device. It is said to have been used in wireless telegraph experiments in Germany up to a distance of ninety-five kilometers.

We must next direct attention to those wave-detecting devices which depend upon magnetization of iron, and here we are able to record recent and most interesting developments. More than seventy years ago, Joseph Henry, in the United States, noticed the effect of an electric spark at a distance upon magnetized needles.† Of recent times, the subject came back into notice through the researches of Professor E. Rutherford,‡ who carried out at Cambridge, England, in 1896, a

* See E. Marx, *Phys. Zeitschrift*, Vol. II., p. 249; *Science Abstracts*, Vol. IV., p. 471. See also German Patent Specification No. 121,663, Class 21a.

† See 'The Scientific Writings of Professor Joseph Henry.'

‡ *Phil. Trans. Roy. Soc. Lond.*, 1897, Vol. 189a, p. 1.

valuable series of experiments on this subject. He found that if a magnetized steel needle or a very small bundle of extremely thin iron wires is magnetized and placed in the interior of a small coil, the ends of which are connected to two long collecting wires, then an electric wave started from a Hertz oscillator at a distance causes an immediate demagnetization of the iron. This demagnetization he detected by means of the movement of the needle of a magnetometer placed near one end of the iron wire. Although Rutherford's wave detector has been much used in scientific research, it was not, in the form in which he used it, a telegraphic instrument, and could not record alphabetic signals.

Not long ago Mr. Marconi invented, however, a telegraphic instrument based upon his discovery that the magnetic hysteresis of iron can be annulled by electric oscillations. In one form, Mr. Marconi's magnetic receiver is constructed as follows* (see Fig. 18): An endless band of thin iron wire composed of several iron wires about No. 36 gauge, arranged in parallel, is made to move slowly round on two pulleys, like the driving belt of a machine. In one part of its path, the wire passes through a glass tube, on which are wound two coils of wire, one a rather short, thick coil, and the other a very fine, long one. The fine, long coil is connected with a telephone, and the shorter coil is connected at one end to the earth and the other to the aerial. Two permanent horseshoe magnets are placed as shown in Fig. 18, with their similar poles together, and, as the iron band passes through their field, a certain length of it is magnetized, and owing to the hysteresis of the material, it retains this magnetism for a short time after it has passed out of the center of the field. If then an electric oscillation, coming down from the aerial, is passed through the shorter coil, it changes the position of the magnetized portion of the iron and, so to speak, brings the magnetized portion of iron back into the position it would have occupied if the iron had had no hysteresis. This action, by varying the magnetic flux through the secondary coil, creates in it an electromotive force which causes a sound to be heard in the telephone connected to it. If at a distant place a single wave or train of waves is started and received by the aerial, this will express itself by making an audible tick in the telephone, and if several groups of closely ad-

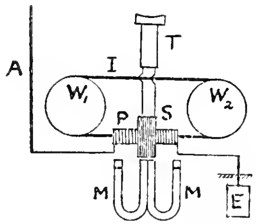


FIG. 18. MARCONI MAGNETIC RECEIVER. W_1 W_2, wheels; *I*, iron wire band *P*, primary coil; *S*, secondary coil; *T*, telephone; *A*, aerial; *E*, earthplate.

* See *Proc. Roy. Soc. Lond.*, June 12, 1902. 'Note on a Magnetic Detector for Electric Waves which can be employed as a Receiver for Space Telegraphy,' by G. Marconi.

jacent wave trains are sent, these will indicate themselves by producing a rapid series of ticks in the telephone, heard as a short continuous noise and taken as equivalent to the Morse *dash*.

It was by means of this remarkably ingenious instrument that Mr. Marconi was able, in the summer of 1902, to detect the waves sent out from Poldhu on the coast of Cornwall, and receive messages as far as Cronstadt in the Baltic, in one direction, and as far as Spezzia in the Mediterranean in another direction, and also to receive messages across the Atlantic from the power stations situated in Glace Bay, Nova Scotia, and from one at Cape Cod in Massachusetts, U. S. A., in December, 1902.

There can be no question that this magnetic detector of Mr. Marconi's, used in connection with a good telephone and an acute human ear, is the most sensitive device yet invented for the detection of electric waves and their utilization in telegraphy without continuous wires. It is marvelously simple, ingenious and yet effective, as a Hertzian wave telegraphic receiver.

Whilst on the subject of magnetic wave detectors, the author may describe experiments that he has been recently making to construct a Hertzian wave detector on the Rutherford principle, which shall be strictly quantitative. All the receivers of the coherer type and electrolytic type give no indications that are at all proportional to the energy of the incident wave. Their indications are more or less accidental and depend upon the manner in which the receiver was last left. There is a great need for a quantitative wave detector, the indications of which shall give us a measure of the energy of the arriving wave. It is only by the possession of such an instrument that we can hope to study properly the sending powers of various transmitters or the efficiency of different forms of aerial or devices by which the wave is produced. This magnetic receiver is constructed as follows:

A coil of fine wire is constructed in sections like the secondary coil of an induction coil, and in the instrument already made, this coil contains thirty or forty thousand turns of wire. In the interior of this coil are placed a number of little bundles of fine iron wire wound round with two coils, a fine wire coil which is a magnetizing coil, and a thicker wire coil which is a demagnetizing coil. These sets of coils are joined up, respectively, in series or in parallel. Then, associated with this form of induction coil is a commutator of a peculiar kind, which performs the following functions when a battery is connected to it and when it is made to revolve by a motor or by clockwork. First, during part of the revolution, the commutator closes the battery circuit and magnetizes the iron cores, and whilst this is taking place the secondary circuit of the induction coil is short-circuited and the galvanometer is disconnected from it. Secondly, the

magnetizing current is stopped, and soon after that the secondary coil is unshortcircuited and connected to the galvanometer, and remains in this condition during the remainder of the revolution. This cycle of operations is repeated at every revolution. If then an electrical oscillation is sent into the demagnetizing coils, and if it continues longer than one revolution of the commutator, it will demagnetize the iron core during that period of time in which the battery is disconnected and the galvanometer connected. The demagnetization of the iron which ensues produces an electromotive force in the secondary coil and causes a deflection of the galvanometer, and this deflection will continue and remain steady if the oscillation persists. Moreover, since this deflection is due to the passage through the galvanometer of a rapid series of discharges, it is large when the oscillations continue for a long time and are powerful, and small when they continue for a short time or are weak. We can, therefore, with this arrangement, receive on the galvanometer, just as on the mirror galvanometer used in submarine cable work, a dot or dash, and, moreover, the magnitude of these deflections is a measure of the energy of the wave.

It is probable that when this arrangement is perfected it will become exceedingly useful for making all kinds of tests and measurements in connection with Hertzian telegraphy, even if it is not sensitive enough to use as a long distance receiver.

Of late years, a variety of wave-detecting devices have been brought forward, which depend upon electrolysis. One of the best known of these is that by De Forest and Smythe.* In this arrangement, a tube contains two small electrodes like plugs, which may be made of tin, silver or nickel, or other metal. The ends of these plugs are flat and separated from each other by about one two-hundredth of an inch. Sometimes the end of one of these plugs is made cup shaped and the cup or recess is filled with a mass of peroxide of lead and glycerine. In the interval between the electrodes is placed an electrolyzable mixture, which consists of glycerine or vaseline mixed with water or alcohol, and a small quantity of litharge and metallic filings. These metallic filings act as secondary electrodes. When a small electromotive force is applied between the terminals of the electrodes of this tube through a very high resistance of twenty or thirty thousand ohms, an exceedingly small current passes through this mixture, and it causes an electrolytic action which results in the production of chains of metallic particles connecting the two electrodes together. If, in addition to this, one terminal or electrode of the arrangement is connected to an aerial wire and the other terminal to the earth, then on the arrival of an electric wave creating oscillations in the wire; these oscillations pass down into the electrolytic cell where they break up the

* See U. S. A. Patent Specification, No. 716,000, Application of July 5, 1901.

chains of metallic particles and thus interrupt the current passing through the telephone quite suddenly, which is heard as a slight tick by an ear applied to it. As soon as the wave ceases, the chain of metallic particles is reestablished, so that the appliance is always in a condition to be affected by a wave. It is said that this breaking up and reformation of the chains of metallic particles is so rapid that a short spark made at the transmitting station is heard as a tick in the telephone, but a rapid succession of oscillatory sparks is heard as a short continuous sound; hence the two signals necessary for alphabetical conversation can be transmitted.

Another receiver which has some resemblance to the above, although different in principle, is that of Neugschwender.* In this arrangement, which to a certain extent resembles the Schäfer detector, a glass plate has upon it a deposit of silver in the form of a strip, which is cut across at one place, thus interrupting it. If the cut is breathed upon or placed in a moist atmosphere, a little dew is deposited upon the glass, which bridges over the cut in the metal and creates an electric continuity. Hence a small current can be passed across the gap and through a telephone by one or two cells of a battery. If, however, an electric oscillation passes across the gap on its way from an aerial to the earth, then the continuity of the liquid film is destroyed and the current is interrupted and a sound created in the telephone.

The opinion has been expressed by Sir Oliver Lodge that in this case the interruption of the circuit which occurs is really due to the coalescence of minute water particles into larger drops, as when vapor is condensed into rain, and hence the continuity of the material is interrupted.

We must then make a brief reference to other kumascopes which depend upon the heating power of an electrical oscillation, which it possesses in common with every other form of electric current. Professor R. A. Fessenden† has constructed a very ingenious thermal receiver in the following manner: An extremely fine platinum wire, about 0.003 of an inch in diameter, is embedded in the middle of a silver wire about one tenth of an inch in diameter, like the wick of a candle. This compound wire is then drawn down until the diameter of the silver wire is only .002 of an inch, and hence the platinum wire in its interior being reduced in the same ratio, will have been drawn to a diameter of 0.00006 of an inch. A short piece of this drawn wire is then bent into a loop and the ends fixed to wires. The tip of the loop is then immersed in nitric acid and dissolved in the silver, leaving an exquisitely fine platinum wire a few hundreds of an inch in

* See *The Electrical Review*, Vol. XLIV., 1899, May 26; *Wied Ann.*, Vol. LXVIII., p. 92; or German Patent Specification, No. 107,843.

† U. S. A. Patent Specification, No. 706,742, 1902.

length and having a resistance of about thirty ohms. This little loop is sealed into a glass bulb like a very small incandescent lamp, or it may be enclosed in a small silver bulb and the air may be exhausted. If an electrical oscillation is sent through this exceedingly fine platinum wire, it heats it and rapidly increases its resistance. The electrical oscillations produced in an aerial are sent through a number of these loops arranged in parallel, and the loops are short-circuited by a telephone, joined in series with a source of very small electromotive force produced by shunting a single cell or opposing to one another two cells of nearly equal electromotive force. Any variation of resistance of the little platinum loops due to the heat produced by the oscillations, by suddenly altering the current flowing through the telephone, will cause a sound to be heard in it. The electrical oscillations when passing through the loops are therefore detected by the heat which they generate in these exquisitely fine platinum wires.

Finally, one word must be said on the subject of electrodynamic receivers, due to the same inventor. An exceedingly small silver ring is suspended by a quartz fiber and has a mirror attached to it in the manner of a galvanometer. This ring is suspended between two coils joined in series, which are placed either in the circuit of the aerial or in the secondary circuit of the small air core transformer inserted between the aerial and the earth. When electrical oscillations travel down the aerial they induce other electrical oscillations in the silver ring, and if the ring is so placed that its normal position is with its plane inclined at an angle of forty-five degrees to the place of the fixed coils, then the ring will be slightly deflected every time an oscillation occurs in the aerial.

Omitting further mention of the details of the kumascopes in use and the receiving aerial, we must next proceed to consider the receiving arrangements taken as a whole.

In the original Marconi system, the sensitive tube or coherer was inserted between the bottom of the receiving aerial and the earth.* Accordingly, when the incident electric wave strikes the receiving aerial and creates in it an oscillatory electromotive force, this last will, if of sufficient amplitude, cause the particles of the coherer to cohere and become conductive. This sudden change from a nearly perfect non-conductivity to a conductive condition is made to act as a switch or relay, closing or completing the circuit of a single cell, and so sending a current through an ordinary telegraphic relay, closing or completing the circuit of a single cell, which may in turn actuate another recording telegraphic instrument, such as a Morse printer. To prevent the oscillations from passing into the relay circuit, small choking

* See British Patent Specification, G. Marconi, No. 12,039, June 2, 1896.

or inductance coils are inserted between the ends of the sensitive tube and the relay and cell and serve to confine the oscillations to the tube.

It has already been pointed out that in the transmiting aerial the amplitude of the potential vibrations increases from the bottom to the top, and when vibrating in its fundamental manner there is a potential node at the earth connection and a potential loop or antinode at the top. The same is true of the receiving aerial. Hence if the kumascope employed is a Branly metallic filings tube and is inserted near the base of the aerial, the difference of potential between its two ends will be small.

It has also been mentioned that a receiver of this type acts in virtue of electromotive force or potential difference, and hence the proper place to insert the coherer is not at the base of the aerial, but between the top of the aerial and the earth. This, however, could not be done by running up another wire from the earth, as that would amount to putting the coherer between the tops of two identical aerials, and between its ends there would be no difference of potential. Professor Slaby, in conjunction with Count von Arco, has given an ingenious solution of this problem. If we take two equal lengths of wire, bent at right angles, and connect the point of intersection with the earth, placing one of these wires vertically and the other horizontally, we then have an arrangement which responds to the impact of electric waves, and has electrical oscillations set up in it in such fashion that the common point of the two wires has a very small amplitude of potential, but the two extremities have equal and large variations. If then we insert a coherer tube between the earth and the outer extremity of the horizontal wire, it is influenced in the same manner as it would be by the potential variations at the top of the vertical wire. In other words, it is acted upon by a large difference of potential instead of a small one. It is not found necessary to stretch the horizontal wire out straight; it may be coiled into a spiral with open turns, and the slight decrease in capacity and increase in inductance resulting from this can be compensated by cutting off a short piece of it.

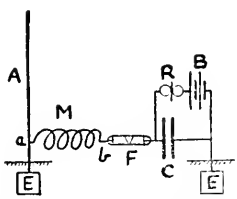


FIG. 19. SLABY RECEIVER. *A*, aerial; *E*, earth plate; *F*, coherer; *M*, multiplier; *C*, condenser; *R*, relay; *B*, battery; *E*, earth plate.

In this way we have an arrangement (see Fig. 19) in which the outer extremity of this open spiral experiences variations of potential which exactly correspond with those at the summit of the vertical aerial. The receiving arrangements are then completed as in Fig. 19, one end of the coherer being attached to the outer end of the spiral and the other end through a condenser to the earth, a relay and a voltaic cell being arranged as shown in the diagram. The mode of operation of this re-

ceiver is as follows: When the wave strikes the aerial it sets up in it electrical oscillations with a potential antinode at the summit, and at the same time a potential antinode is created at the outer end of the spiral attached near the base of the aerial; this spiral being called by Professor Slaby a *multiplicator.* As long as the coherer tube remains non-conductive, the local cell can not send a current through the relay, but, as soon as the resistance is broken down by the impact of a wave, the local cell sends a current through the coherer tube which, passing down to the earth through the base of the aerial and up through the earth connection to the condenser, completes its circuit through the relay. Many variations of this arrangement have been made by Slaby and Von Arco and by the Allgemeine Elektricitäts Gesellschaft of Berlin.

In 1898, Mr. Marconi made a great advance in the construction of his receiving apparatus by the insertion of his 'jigger' or oscillation transformer in the aerial receiving circuit.* In this arrangement, the primary coil of an air core transformer wound in a particular way is inserted between the receiving aerial and the earth, and the secondary circuit is cut in the middle and connected to the two surfaces of a condenser, these surfaces being also connected through the circuit of an ordinary telegraphic relay and a single cell (see Fig. 20). The ends of the secondary circuit of this oscillation transformer are also connected to the terminals of the coherer tube, and these again are short-circuited by a small condenser.

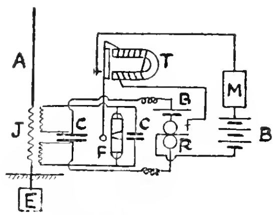


FIG. 20. MARCONI RECEIVER. *A*, aerial; *J*, jigger; *CC*, condensers; *F*, filings tube; *T*, tapper; *R*, relay; *B*, battery; *M*, Morse printer.

The operation of this receiver is as follows: The oscillations set up in the aerial pass through the primary circuit of the jigger, and these induce other oscillations in the secondary circuit; the electromotive force or difference of potential between the primary terminals being transformed up in any desired ratio. It is this exalted electromotive force which is made to act on the coherer tube, and, inasmuch as the jigger operates in virtue of a current passing through its primary circuit and this current is at a maximum at the lower end of the aerial, the arrangement is exceedingly effective, because it, so to speak, converts current into voltage. At the lower end of the aerial, although the amplitude of the potential oscillations is a minimum, the amplitude of the current oscillations is a maximum, and the jigger transforms these large current oscillations into large potential oscillations, *provided it is constructed in the right manner.* We can also transform up or increase the amplitude of the small potential variations near the bottom of the aerial by employing the principle of

* See G. Marconi, British Patent Specification, No. 12,326, of June 1, 1898.

resonance. Many devices of this kind due to Professor Slaby and others have been suggested and tried but the details are rather too technical to be fully described here.

It will be noticed that the receiving aerial may be arranged in one of two ways—it may be either earthed at the lower end or it may be insulated. It has been claimed that there is a great advantage in earthing the receiving aerial directly in that it eliminates atmospheric disturbances.

We shall allude to this point more particularly later on. Meanwhile it may be mentioned that the receiving arrangements, as a whole, constitute a sensitive arrangement, as shown by Popoff, Tommasina and by all the large experience of Mr. Marconi himself for detecting changes in the electrical condition of the atmosphere, which are doubtless of the nature of electrical oscillations. On the other hand, the receiving arrangements may be perfectly insulated, and some experimentalists have asserted that by this method the greatest freedom is secured from atmospheric disturbances. Amongst the non-earthed arrangements the system invented by Professor F. Braun, of Strasburg, and worked by Messrs. Siemens, of Berlin, may be mentioned.*

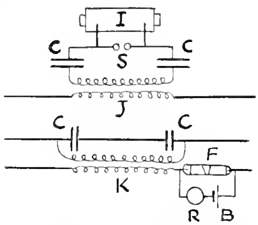


FIG. 21. BRAUN'S NON-EARTHED RECEIVER. *I*, induction coil; *C*, *C*, condensers; *S*, spark gap; *J*, transmitting jigger; *K*, receiving jigger; *F*, filings tube; *R*, relay; *B*, battery.

Professor Braun's arrangements are indicated in the diagram in Fig. 21. In this case, an induction coil is used to create a discharge between two spark balls, and to these two balls are connected the two outer coatings of two condensers, the inner coatings of which are connected together through the primary coil of an air core transformer. The secondary coil of this transformer is connected to two extension wires forming a Hertz resonator, and the length of these wires is so adjusted with reference to the time period of the primary circuit that they resonate to it, the whole length from end to end of the secondary circuit being half a wave length. The receiver, as shown in the diagram, consists of a pair of quarter wave length receiving wires connected through two condensers, which are shortcircuited by the primary coil of an oscillation transformer. The secondary circuit of this last oscillation transformer has two extension wires to it, turned in the same manner, to respond to the primary oscillator; and in the circuit of one of these extension wires is placed a coherer tube, shortcircuited by a relay and a local battery.

It will thus be seen that there is an entire abolition of ground con-

* See *The Electrical Review*, September 26, 1902, Vol. LI., p. 543.

nection, which, Professor Braun claims, practically avoids all atmospheric disturbances.* The details of the receiving arrangement are as follows: The coherer tube consists of an ebonite tube containing hard steel particles of a uniform size, placed in the adjustable space between two polished steel electrodes. It is found that with this steel coherer, a small amount of magnetism in the particles increases its sensitiveness, and to obtain this, a ring magnet is employed in connection with a coherer tube. Receiving apparatus arranged on this system is said to have been used for telegraphing between Heligoland and Cuxhaven, a distance of thirty-six miles.

All the immense experience, however, gained by Mr. Marconi and those who have worked with his system, is in favor of using the earth connection. There is no doubt that Hertzian wave telegraphy can be conducted over short distances by means of totally insulated aerials, but for long distances the earth connection is essential, for the reasons that have been explained previously.

There are many of the details of the receiving arrangements which remain to be considered. If the communication is received by a telegraphic instrument like the Morse printer, which requires a current of anything like ten milliamperes to work it, then an important element in the receiving arrangement is the relay. The relay that is generally used is a modified form of the Siemens polarized relay, which is so adjusted as to make a single contact. For marine work on board ship, it is essential that this relay shall be balanced so that variations in position shall not affect it. Sometimes the relay is hung in gimbals like a compass, and at other times suspended from a support by elastic bands, so as to avoid jolting. In any case, the relay must be so adjusted that no change of position will cause it to close the circuit of the telegraphic printer or recorder. Its sensibility ought to be such that it is actuated by a tenth of a milliampere, and, if possible, even by less. The alteration of sensibility in the ordinary contact form of relay is the pressure that is necessary to bring the platinum points of the circuit closer together, so as to pass the minimum current which will work the telegraph printer.

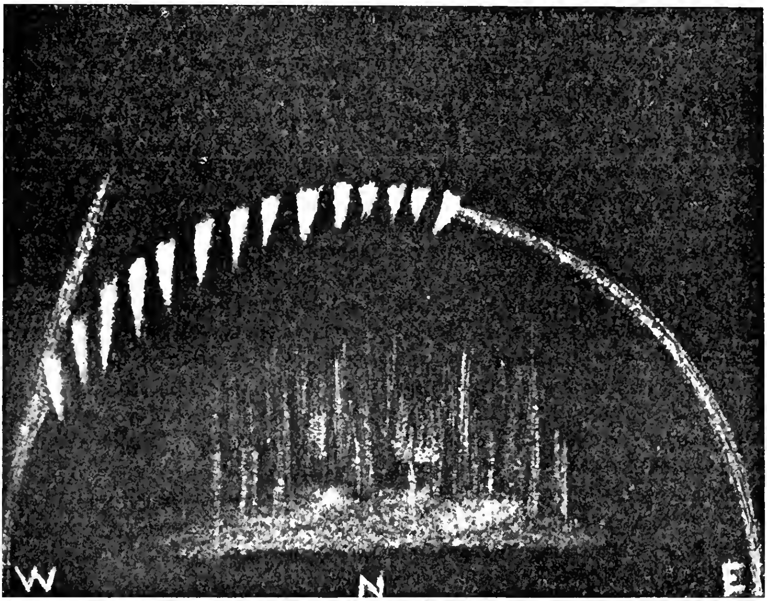
The important matter, however, in connection with the use of the relay in Hertzian wave telegraphy, is that it should be capable of adjustment without extraordinary skill. It is no use to put into the hands of an operator a relay which requires abnormal dexterity to make it work at all.

* There is a good deal of contradiction between various inventors on this point, some saying that 'earthed' aerials obviate atmospheric electrical disturbances, and others that insulated aerials are in this respect superior. The truth appears to be that neither form is absolutely free from risk of disturbance by this cause.

SHORTER ARTICLES AND CORRESPONDENCE.

AN UNUSUAL AURORA BOREALIS.

THERE was one feature of the aurora of August 21, as seen from York Harbor, Maine, of so extraordinary a character as to deserve permanent record. I refer to the arch extending from east to west with its pendant comet-like attachments as shown in the illustration, which last, though unskilfully drawn, gives a fairly correct diagrammatic representation of the phenomenon.



AN UNUSUAL AURORA BOREALIS.

It was a clear starlit night with a low bank of cloud along the northwestern horizon. No moon. The display began between 7 and 8 P.M., with the usual nebulous luminosity in the northern sky with occasional streaks shooting upwards. These gradually became fainter and of but little interest, when, at 9.30 P.M., there appeared a magnificent arch spanning the heavens from east to west, the top of the arch being a little north of the zenith, and almost overhead. As shown in the diagram at least three fourths of the eastern half of the arch consisted of a pale, only half-luminous column of visible streaks, the band being perhaps as wide as the diameter of a full moon appears to be. The western segment of the arch presented a most extraordinary and magnificent spectacle.

Beginning a little east of the zenith and continuing almost to the western horizon, there appeared what might easily be likened to a string of tremendous comets. These pennants of

light, however—unlike comets—were more brilliant at their bases, less so at their apices. Their bases were directed upwards, their points down. They were constantly changing, appearing and disappearing, but not very rapidly. Some would remain a minute or more without much variation. The number varied from ten to fifteen. They were shorter toward the zenith, longer toward the horizon. At the western end of the arch, one long half-luminous streak shot up obliquely (as shown in the figure) and remained for some minutes after the arch itself had disappeared. The arch lasted from 9.30 to nearly 10 P.M.

In size the comet-like pendants appeared about as wide at their bases as the diameter of a full moon, and four or five times such a diameter in length. I reach this estimate by comparing my own conception with those of several others who made observations at the same time.

It should be noted that no visible connection existed between the arch and the nebulous masses and streaks of light near the northern horizon.

In looking at the diagram the reader may well conceive it to be too toy-like and artificial to come within the range of truth or possibility, but so was the arch itself. No one could have conceived such a display to be either natural or possible. To some it suggested a festive arch adorned with luminous cornucopias, like a Christmas decoration. Those of us who a few weeks before had obtained telescopic views of Barelli's comet with some difficulty, seemed now to be rewarded by nature exhibiting a whole string of far more brilliant comets for our special delectation. The kind and degree of luminosity appeared to be almost exactly like that of the comet when seen through a good glass.

The splendor and magnificence of the display were beyond description; startlingly beautiful. The spectacle seemed almost to overstep the modesty of nature, but its coming unheralded during the majestic silence of the night served to banish so unjust a thought. Surprise, delight, admiration and awe—these were the feelings that thrilled with pleasure those of us who witnessed the sublime and mysterious scene—a scene that few of us will ever see again.

The last we saw of this aurora was at midnight when a diffuse light behind a low bank of cloud near the northern horizon gave the appearance as of a moon about to rise. But a medical acquaintance—Dr. S. W. Allen—who was out at 2 A.M. saw shimmering waves of iridescent light streaming radially upwards from the horizon towards a central point at the zenith, a not very unusual phenomenon which many of us have seen once or more during the last half century.

Auroral arches from east to west have been observed in the Arctic regions; double and triple ones are recorded by Mr. E. B. Baldwin in Peary's 'Northward over the Great Ice,' vol. 2, p. 191 *et seq.*, but in this country they are certainly very unusual. Baldwin describes one in which the arch formed itself into a luminous curtain, and the curtain folds knotted 'themselves into a series of electric balls suspended in the same arch-order' (p. 198). These globes of light may have had some approaching resemblance to the comet-like pennants of light I have endeavored to describe.

A. F. A. KING.

SCIENCE AND PHILOSOPHY.

TO THE EDITOR: In the first two paragraphs of Sir Oliver Lodge's admirable address entitled 'Modern Views on Matter,' published in the August number of this journal, he alludes to a distinction between the scientific aspects and the philosophical aspects of his subject and hastens to disclaim any qualifications for discussing the lat-

ter. Thus in the first paragraph he says:

> The nature of matter has been regarded by philosophers from many points of view, but it is not from any philosophic standpoint that I presume in this university to ask you to consider the subject under my guidance.

And in the second paragraph he adds:

> If I may venture to say so, it is the more philosophic side of physics which has always seemed to me the most suitable for study in this university; and although I disclaim any competence for philosophic treatment, in the technical sense, yet I doubt not that the new views, in so far as they turn out to be true views, will have a bearing on the theory of matter in all future writings on philosophy; besides exercising a profound effect on the pure science of physics and chemistry, and perhaps having some influence on certain aspects of biology also.

The course which Sir Oliver followed on the occasion of this Romanes Lecture is not without eminent precedent. Many a man of science has acknowledged subserviency to philosophy on similar occasions; and there is no doubt that the most of us have inherited a belief in the inferiority of science to philosophy. But the question I would ask is whether such subserviency and such belief are any longer justified and hence dignified?

This, of course, raises squarely the question of the distinction between science and philosophy. I assume, however, that it is unnecessary to thrash over old straw here and now. Brushing aside pseudo-science and barren philosophy, what is the distinction, if any, between sound science and sane philosophy?

If one applies the scientific method of investigation to scientists and to philosophers of the modern types he will find, I think, that they are very much alike and that neither claims any superiority over the other. It would appear also that the two words science and philosophy are now very frequently used as synonymous in spite of their widely differing shades of meaning.

Why then should we prolong distinctions which are no longer tenable? Why, to return to the Romanes Lecture, should we be asked to entertain the hypothesis that some Oxford philosopher is more likely to see straight with respect to the intricate properties of matter than Sir Oliver himself? How much, in fact, has all philosophy, in the sense in which Sir Oliver uses the word, contributed to our knowledge of matter? There was a time when every obscure professor of 'moral' or 'mental' philosophy was held, by common consent of the educated, more competent to judge of the philosophic aspects of the 'Origin of Species' than Charles Darwin. But have we not outlived that time, and is not a relapse to the ways of that time, even for the purposes of compliment, reprehensible?

PHYSICIST.

[The point of our correspondent appears to be well taken. But possibly Sir Oliver Lodge's compliment implied that experimental science has been neglected at Oxford.—ED.]

THE PROGRESS OF SCIENCE.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

For the first time in many years there has been this summer no meeting of the American Association. It will be remembered that the Association held a winter meeting at Washington during convocation week and adjourned to meet at St. Louis a year later. The lack of a summer meeting is in some ways to be regretted. For the presentation of scientific work by specialists to specialists, the most business-like meetings can be held in the winter; but for social intercourse and especially for the bringing of those not specially engaged in scientific work in contact with men of science, a summer meeting with a certain amount of open-air leisure seems to be desirable. Many of our societies continue to meet in the summer, and it seems that the American Association should provide a center. For example, this year the American Mathematical Society met in Boston, the American Chemical Society in Cleveland, the Society for the Promotion of Engineering Education at Niagara Falls, etc. For a general meeting of scientific men, we must, however, turn this summer to the congresses in France, Germany, Great Britain and other foreign countries.

The British Association met at Southport, beginning on September 9, under the presidency of Sir Norman Lockyer, known for his contributions to astronomy and as editor of *Nature*. In the latter capacity, he has been much interested in the endowment of research work, which he treated in the presidential address from which we quote below. In addition to this address evening lectures were given by Dr. Robert Monroe on man as artist and sportsman in the paleolithic period; by Dr. Arthur Roe on the Old Chalk Sea and some of its teachings, and by Dr. J. S. Flett on the volcanic eruptions in the West Indies. Then there were the usual addresses before the sections—Professor W. Noel Hartley, before the section of chemistry, reviewed the work of spectroscopy of the last twenty-five years and discussed especially its relation to the investigation of the composition of matter and of chemical theory; Professor W. W. Watts, before the section of geology, laid special stress on the value of geology as an educational subject; Professor Sydney J. Hickson, before the section of zoology, reviewed the question of the influence of environment in the production of variation in animals with special reference to the cœlenterata; Captain E. W. Creak, before the section of geography, spoke of the connection between geography and terrestrial magnetism, explaining what has latterly been done in the direction of magnetic surveys and what is still needed; the subject of the address of Mr. E. W. Bradbrook before the section of economics was 'Thrift'; Professor J. Symington in addressing the anthropological section discussed the significance of variations in cranial forms with special reference to fossil man; Mr. A. C. Seward, before the section of botany, reviewed the geographical distribution of fossil plants.

The programs of the sections contain the usual number of interesting papers. The International Meteorological Committee met at Southport in conjunction with the association;

the papers included a survey of the relation of solar and terrestrial changes by Sir Norman Lockyer. The new discoveries regarding the constitution of matter and radiation, a scientific advance the far reaching character of which we can scarcely appreciate, was naturally prominent in the physical section. The papers included one by Professor Rutherford, of Montreal, whose important investigations on the emanations from radium were described by Sir Oliver Lodge in a recent issue of the MONTHLY. The subject chosen for special discussion in the chemical section was 'Combustion.' The geological section conflicted with the International Congress of Geology at Vienna, but the program contained many papers. The subject of 'fertilization' was especially discussed in the zoological section, Professor E. B. Wilson, of Columbia University, being one of those taking part. The British Antarctic Expedition was naturally the subject of special interest to the geographers, while the fiscal questions brought forward by Mr. Chamberlain's proposed abandonment of free trade attracted the economists.

The association will meet next year at Cambridge under the presidency of Mr. Arthur Balfour, the prime minister: the following year the meeting will be in South Africa.

SIR NORMAN LOCKYER ON THE ENDOWMENT OF EDUCATION AND RESEARCH.

THE presidential address of Sir Norman Lockyer before the British Association was entitled 'The Influence of Brain Power on History.' The speaker laid special stress on the need of greater endowments for higher education and research from the government, and advocated duplicating the Navy estimates of 1888–9, £24,000,000 and devoting that amount to the increase of Great Britain's brain power. He said: Our position as a nation, our success as merchants, are in peril chiefly—dealing with preventable causes—because of our lack of completely efficient universities and our neglect of research.

What are the facts relating to private endowment in this country? In spite of the munificence displayed by a small number of individuals in some localities, the truth must be spoken. In depending in our country upon this form of endowment we are trusting to a broken reed. If we take the twelve English university colleges, the forerunners of universities unless we are to perish from a lack of knowledge, we find that private effort during sixty years has found less than £4,000,000; that is, £2,000,000 for buildings and £40,000 a year's income. This gives us an average of £166 000 for buildings and £3,300 for yearly income.

What is the scale of private effort we have to compete with in regard to the American universities? In the United States, during the last few years, universities and colleges have received more than £40,000,000 from this source alone; private effort supplied nearly £7,000,000 in the years 1898–1900.

Next consider the amount of state aid to universities afforded in Germany. The buildings of the new University of Strasburg have already cost nearly £1,000,000; that is, about as much as has yet been found by private effort for buildings in Manchester, Liverpool, Birmingham, Bristol, Newcastle and Sheffield. The government's annual endowment of the same German university is more than £49,000.

When we consider the large endowments of university education both in the United States and Germany, it is obvious that state aid only can make any valid competition possible with either. The more we study the facts, the more statistics are gone into, the more do we find that we, to a large extent, lack both of the sources of endowment upon one or other or both of which other nations depend. We are

Nicholas Murray Butler

between two stools, and the prospect is hopeless without some drastic changes. And first among these, if we intend to get out of the present slough of despond, must be the giving up of the idea of relying upon private effort.

THE SCHOOL OF JOURNALISM OF COLUMBIA UNIVERSITY.

THE endowment of a school of journalism at Columbia University by Mr. J. Pulitzer has been widely discussed by the press, which it so nearly concerns. There is much difference of opinion as to the value of such a school. It is argued that a newspaper man can get his training best in the office of a newspaper, and that the information of the editor, correspondent and reporter is too general and transient to be the subject of a course of study. On the other hand, it is pointed out that in the other professions there has been a transition from the apprentice method to the professional school, and that schools of journalism may become as essential as schools of law or medicine. It is certainly true that the technical equipment of the journalist is less extensive and definite than that of the physician, the lawyer or the engineer. Preparation for journalism seems, however, to parallel pretty closely preparation for the church or for teaching. The divinity student learns Greek, Hebrew, ecclesiastical history, systematic theology and the like, and it is well that he should do so as a matter of training, but the speedy oblivion that usually follows does not decrease the value of his services as a clergyman; on the contrary, the less he concerns himself with the book of Genesis and any definite system of theology the better. It is well for the clergyman to be a scholar, but Horace or the French Revolution will serve as well as the church fathers. The conditions are similar for the intending teacher. He must know the subject that he is to teach, but this is given in the ordinary college and university courses, as are also English, psychology and other subjects that should be studied. The history and principles of education are about as useful for the teacher as ecclesiastical history and systematic theology for the clergyman. A man can not be taught in a school either to preach or to teach. Yet theological schools and normal schools are on the whole useful institutions. Schools of journalism will probably soon be regarded as equally essential.

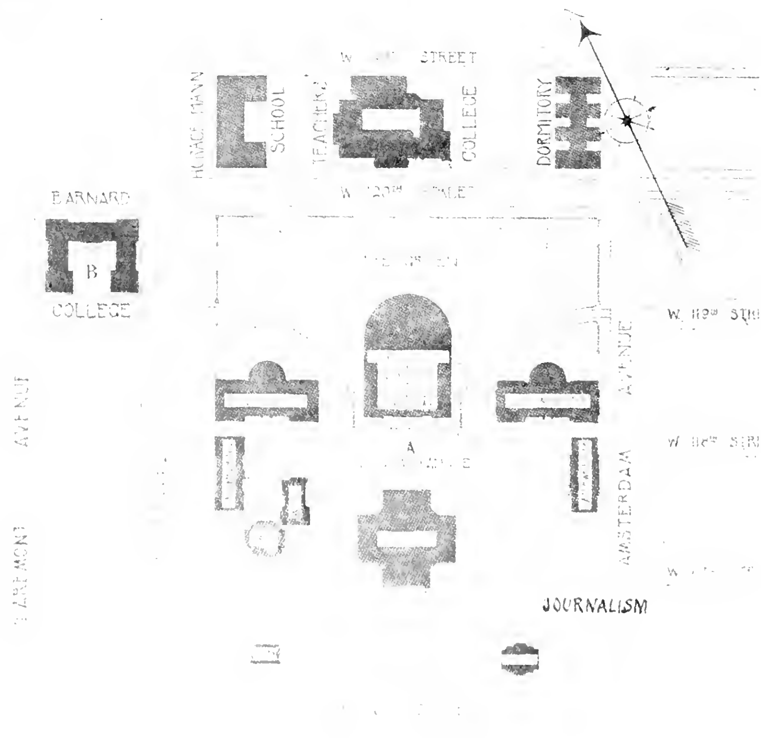
The uses of such schools are partly indirect. They serve for example as selective agencies. Men having talent and ambition frequent such schools, and those quite unfit are eliminated before graduation. Even supposing that four years in an engineering school give no better training than actual work in a shop, still those who graduate from the school are likely to be better men than those who do not—employers run less risk in choosing them. Graduates from the Columbia University School of Journalism will probably deserve advancement better and secure it more easily than those who spend the same years in a newspaper office. The coming together of a large number of men having similar interests and plans tends to encourage and stimulate them. When they form part of a great university, where investigation is continually in progress and high ideals of conduct and culture are maintained, they will insensibly conform to their surroundings.

But there are also certain direct uses of professional schools even in subjects such as teaching, commerce and journalism. The student may pursue the same studies as in the ordinary college course, but the quantity and emphasis are different. The intending journalist should study more English, history and political science than the intending physician, and should study them by somewhat different methods. Then there is a certain

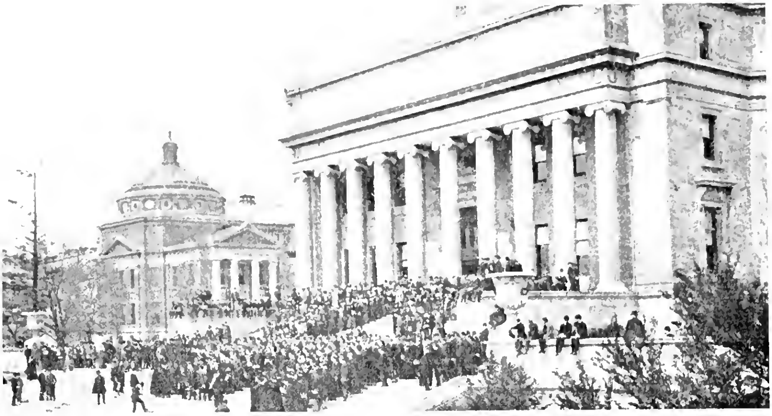
amount of technical information and skill, small in journalism as compared with medicine or engineering, but still deserving treatment in a systematic and broad manner, and more quickly and thoroughly learned in special courses than in actual practice. It is especially the case in a large office that a man has but small opportunity of learning anything except the particular work assigned to him, although it would be for his advantage to know something of the work of other departments. In the case of teachers, summer schools at the universities have proved extremely useful. Similar short courses for journalists will doubtless be given in the new school. The combination of the theoretical study of general principles in a university with practical work under experts is probably the best kind of education for every profession.

Columbia University established the first university school for teachers. This has continually grown in students, in endowments and in efficiency, and has served as a model for other institutions. The school of journalism will doubtless repeat this history. It begins with a generous endowment, Mr. Pulitzer having given a million dollars and having conditionally promised a second million. A building to cost about $500,000 will be erected at once on the site shown in the plan. It will be directly on the right hand of the magnificent entrance to the library here illustrated.

President Butler, whose portrait is reproduced, was elected president of Columbia University on January 6,



Plan of the Buildings and Grounds of Columbia University.



ENTRANCE TO THE LIBRARY OF COLUMBIA UNIVERSITY.

1902. In the short period that has elapsed the university has accomplished much, both on the educational and on the material side. In addition to the school of journalism, there have been various other large gifts, including a dormitory costing $300,000. Teachers College is erecting a building for physical education at a cost of over $250,000. Barnard College has been given the three blocks of land shown on the plan south of the college, which cost about $1,000,000; and the trustees of Columbia College have purchased, at a cost of nearly $2,000,000, the two large blocks south of the present site.

THE EMPLOYMENT OF WOMEN.

THE MASSACHUSETTS BUREAU OF STATISTICS has published some rather interesting information in regard to the occupations of the sexes in the state. In 1900 there were 1,208,491 persons engaged in gainful occupations, 72.77 per cent. of whom were men and 27.23 per cent. women. Thirty years before the percentages were 77.87 for men and 22.13 for women. In 1870 the number of females employed in gainful occupations formed 17.03 per cent. of the total number of females of all ages, and in 1900 the percentage rose to 22.88. About one half of all females are under the age of twenty years, and although many of these are employed, there are many above that age who are invalids or the like. It appears that in a very general way it may be said that one third of all women able to work were employed in gainful occupations in 1870 and one half in 1900. Should this increase be maintained, all women able to work would be engaged in earning money one hundred and twenty years hence.

The kind of work is analyzed in the report in great detail, the recapitulation being as follows:

	Males.	Females.	Both Sexes.
THE STATE.	786,454	292,636	1,079,090
Government	17,240	2,846	20,086
Professional	23,845	19,923	43 768
Domestic service	14,782	79,265	94,047
Personal service	25,724	19 762	45,486
Trade	129,875	24,142	154,017
Transportation	69,680	368	70 048
Agriculture	37,281	275	37,556
The Fisheries	8,813	18	8,831
Manufactures	349,546	142,951	492,497
Mining	2,367	—	2,367
Laborers	98,758	207	98,965
Apprentices	5,320	567	5 887
Children at work	3,223	2,312	5,535

It will be noticed that very few women are employed in transportation, agriculture or as laborers. Indeed it seems somewhat remarkable that only 275 women should be engaged in

agriculture, 207 as laborers, 18 in the fisheries and 3 as carpenters. Agriculture and out-of-door labor are the most healthful occupations, and would not affect the health of women, as do the sedentary occupations to which they are especially attracted. There are 15,830 female teachers, 11,357 bookkeepers, 6,412 clerks and copyists and 5,693 stenographers. There were in 1885 only 106 stenographers. Less than three per cent. of the teachers are married and about 5 per cent. of the clerks and bookkeepers.

The compilers of the report abstain from comments on the sociological significance of the figures they give, but they obviously have these in mind as statistics are added as to marriage, birth, death and divorce rates. In 1851, there were about 28 births per thousand of the population, about 23 marriages, and nearly 19 deaths. In 1901, the ratio of births fell to about 25, marriages to about 17, and deaths to nearly 17. There has been an extraordinary increase in the divorce rate, there having been one divorce to thirty-four marriages in 1882, one to twenty-seven in 1891 and one to eighteen in 1901. The decrease in the marriage and birth rates becomes much more significant when it is remembered that the proportion of native-born inhabitants has greatly decreased. In 1882, 55.74 per cent. of those married were native-born, in 1891, only 43.56 per cent. The foreign-born have much larger families, and the birth rate has decreased much more than three per thousand. How far the decrease is due to the increased employment of women in gainful occupations is a question that deserves serious consideration.

SCIENTIFIC ITEMS.

We note with regret the deaths of Dr. Frederick Law Olmsted, the eminent landscape architect; of Dr. Emmanuel Munk, associate professor of physiology at Berlin, and of Dr. C. K. Hoffman, professor of zoology and comparative anatomy at Harlem.

Among honors conferred on American men of science by foreign institutions we notice that Dr. E. C. Pickering, director of the Harvard College Observatory, has been given the doctorate of science by the University of Heidelberg, and Dr. E. B. Wilson, professor of zoology at Columbia University, has been elected a foreign member of the Accademia dei Lincei of Rome.

Dr. E. B. Copeland, instructor in bionomics at Stanford University, has been appointed chief botanist of the United States Philippine Commission.—Dr. William J. Holland, director of the Carnegie Museum of Pittsburg, has returned to the United States with the important paleontological collections of Baron de Briet, which the Carnegie Museum has recently acquired.—Dr. Emil Tietze, director of the Imperial Geological Institute of Austria, was chosen president of the Ninth International Geological Congress, which opened at Vienna on August 20.

The ship *Terra Nova* has now sailed from England to relieve the *Discovery*. The British government, which has appropriated £45,000 for the expedition, is acting without the advice of the Royal Geographical Society and the Royal Society, which originally sent the expedition, assisted by a grant from the government.

INDEX.

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CONTENTS

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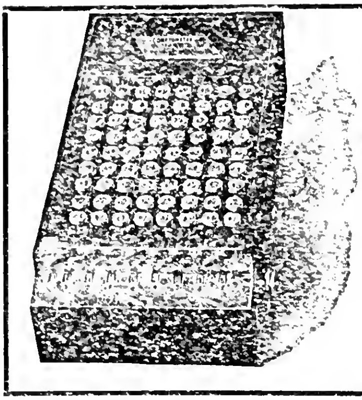

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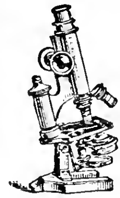

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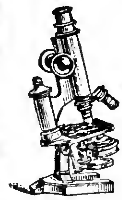

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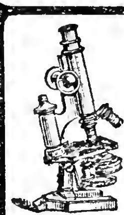

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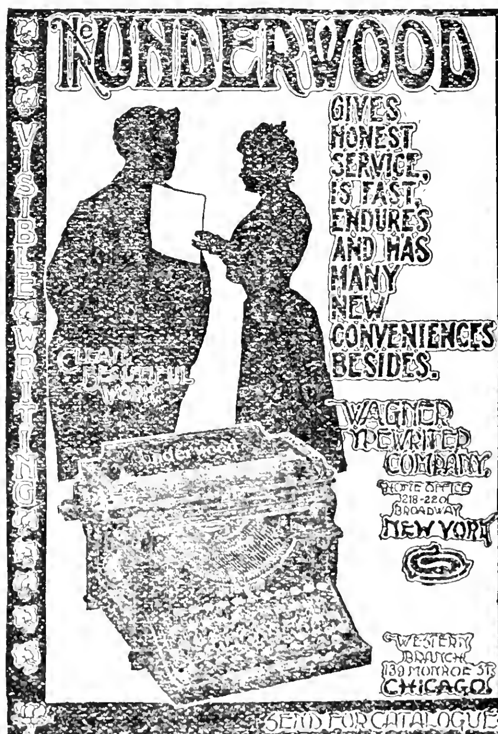

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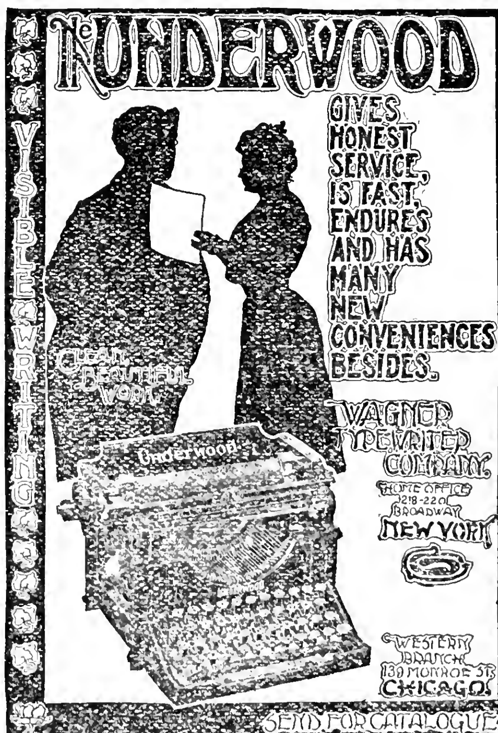

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CONTENTS

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